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Computation, Mathematics and Logistics Department
Test and Evaluation Report

Test and Evaluation of the Navy Technical Information Presentation System (NTIPS) F-14A Field Test Results

by

Joseph J. Fuller
Theodore J. Post (ESSEX Corp.)
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DTRC-88/036 Test and Evaluation of the Navy Technical Information Presentation System (NTIPS) F-14A Field Test Results

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This document describes the results of one part of a full-scale system test of concepts for improvement of quality and of display of Navy System-related Technical Information developed by the Navy Technical Information Presentation System (NTIPS). The tests involved comparisons of three types of experimental Technical Information (TI) with the conventional paper work package. The three types of experimental TI were (1) NTIPS automated troubleshooting TI (called Fault Isolation by Nodal Dependency, FIND), electronically displayed; (2) NTIPS electronically displayed corrective-maintenance TI; and (3) NTIPS corrective-maintenance TI delivered on paper.

Tests were carried out at Miramar Naval Air Station using an operational F-14A aircraft (with introduced "faults"). Test subjects were squadron Aviation Electricians Mates (AEs) both experienced and inexperienced.

All test objectives were achieved. The test demonstrated that electronic display → over

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of maintenance TI is highly acceptable to fleet personnel (90% of the test subjects favored electronic display), that NTIPS-proposed modifications to TI are as effective or more effective than conventional TI in supporting troubleshooting and corrective maintenance, and that automated troubleshooting produced a highly significant improvement in fault-isolation success.

The test provided valuable experience and indicated areas in which NTIPS and electronic display can be improved. Proposals resulting from the test are currently being implemented. (KF) ←

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ABSTRACT

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Tests were carried out at Miramar Naval Air Station using an operational F-14A aircraft (with introduced "faults"). Test subjects were squadron Aviation Electrician's Mates (AEs) both experienced and inexperienced.

All test objectives were achieved. The tests demonstrated that electronic display of maintenance TI is highly acceptable to fleet personnel (90% of the test subjects favored electronic display), that NTIPS-proposed modifications to TI are as effective or more effective than conventional TI in supporting troubleshooting and corrective maintenance, and that automated troubleshooting produced a highly significant improvement in fault-isolation success.

The tests provided valuable experience and indicated areas in which NTIPS TI and electronic display can be improved. Proposals resulting from the test are currently being implemented.

ADMINISTRATIVE INFORMATION

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All the maintenance technicians who gave of their time to serve as test subjects did so conscientiously and with great attention to detail. The organizations at Miramar NAS who provided these technicians were the NAMTRADET, the AIMD, and squadrons VF-124, VF-114, VF-24, VF-211, VF-213, VF-301, VF-1, VF-154, VF-2, and VF-21. Their cooperation is much appreciated.

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1.0 TEST SUMMARY

1.1 BACKGROUND AND PURPOSE

This report describes an operational field test of the Navy Technical Information Presentation System (NTIPS), a system that has been designed to improve the quality of Technical Information (TI) for logistic support of Navy weapons systems and to reduce the difficulty and expense of acquiring and managing it. NTIPS maximizes reliance on automated systems, starting with documentation specifications and authoring procedures and culminating in the electronic delivery of TI to the technician at the maintenance site. NTIPS is currently in Phase III: Test and Evaluation. During the spring and summer of 1986, a test plan* was developed for comparing TI generated with NTIPS procedures and according to NTIPS specifications to conventional paper work-package Technical Manuals used to support maintenance on the F-14A fighter aircraft. A pretest of the plan was conducted in September at the Miramar Naval Air Station, with the full test occurring in October. The objectives of the field test were as follows:

- o Compare the performance of enlisted maintenance technicians using the TI prepared under NTIPS procedures with the performance of technicians using conventional TI (the paper F-14A Technical Manual).
- o Compare technicians' performance when guided by TI printed on paper versus TI presented via an electronic medium.
- o Establish which design characteristics of NTIPS TI are most effective or least effective in an operational situation.
- o Assess user acceptance of certain features (medium, content, format, and style) of the NTIPS TI presentation.

All these objectives were achieved. This section provides an overview of the test design, test executions, and test results. In carrying out this field test of NTIPS TI, an off-the-shelf electronic delivery device was used. The test was designed not to test fielded hardware, but rather to test NTIPS approaches to (1) creating TI that is expected to be intrinsically more effective than conventional TI, and (2) displaying this TI electronically and reducing reliance on paper manuals. In addition, the test was designed to provide

*NAVY TECHNICAL INFORMATION PRESENTATION PROGRAM. Phase III Test and Evaluation of the Navy Technical Information Presentation System. F-14A Experimental Technical Information Test Plan. September 1986 (Essex Corporation) guidance in establishing areas of needed improvement to the TI and the delivery device, as well as to demonstrate the current effectiveness of the NTIPS approaches.

1.2 TEST SITE AND TEST PERSONNEL

The field test was conducted at NAS Miramar, California in the maintenance training areas of this Air Station. The test utilized a fully operational F-14A aircraft (from VF-124). The subjects were active-duty Aviation Electrician's Mates (AE's) made available by Commander, Fighter Airborne Early Warning Wing, Pacific (COMFITAEWWINGPAC) from a number of the squadrons under his command.* These technicians were segregated into experienced and inexperienced groups based on the extent of their relevant hands-on maintenance experience with the F-14A and on the judgment of the maintenance Chief from VF-124 FRAMP, the Fleet Replacement Aviation Maintenance Personnel, the training organization at Miramar. When performing multiperson tasks, test subjects were assisted by FRAMP instructors. These instructors also served as test coordinators. Other test personnel included a Test Director and video crew from the David Taylor Naval Ship Research and Development Center (DTNSRDC), two data collectors from Essex Corporation, and a computer specialist from Hughes Aircraft.

1.3 SCOPE OF THE TEST

To establish the test conditions, faults were deliberately introduced into the aircraft by the test coordinators. This fault insertion permitted the test to include performance of both troubleshooting (fault verification followed by fault isolation) and corrective-maintenance tasks on the Rudder Manual Trim System (RMTS) of the F-14A. A VIDS/MAF (Visual Display Systems/Maintenance Action Form) stating "Rudder Trim Inop" was used to initiate test subjects' performance. On the basis of this standard approach to initiating a maintenance action, the test subject was asked to verify and isolate the cause of the fault introduced into the aircraft. For fault isolation (troubleshooting), half of the test subjects used the NTIPS electronic display system (Fault Isolation by Nodal Dependency - FIND), while the other half used conventional paper work-package Technical Manual material containing primarily schematics.

*Participating organizations were: NAMTRADET, AIMD, VF-123, VF-114, VF-24, VF-211, VF-213, VF-301, VF-1, VF-154, VF-2, VF-21.

In order to provide an adequate set of corrective-maintenance tasks for test purposes, experimental TI was prepared for five tasks:

- o Remove the Directional Trim Actuator (DTA), a component of the Rudder Manual Trim System
- o Reinstall the DTA
- o Zero the Rudder Protractor
- o Attach the Rudder Protractor
- o Check and Adjust Rudder Positioning

Three types of TI were used for corrective maintenance: NTIPS TI presented electronically, NTIPS TI presented in a paper form, and conventional paper work-package Technical Manuals.

The types of troubleshooting and corrective-maintenance TI were compared by evaluating the performance of technicians using each TI type. Performance measures included time required for successful completion of the task (performance times) and number of errors committed by technicians during task performance. These measures were supplemented by the subjects' own evaluations, obtained by questionnaires, of the usefulness and effectiveness of each type of TI for performing both troubleshooting and corrective maintenance.

1.4 TEST EVENTS

After the experimental Technical Information was prepared and reviewed, the field test consisted of the following events:

1. Dry Run of Test Scenario at NAS, Miramar, 2 May 1986. Test personnel observed a walk-through of the test procedures by an inexperienced AZ-3 technician to establish time and physical relationship factors, assess the need to make changes in the test plan prior to the pretest event, and work out relationships between test observers, test subjects, and the test support personnel from Miramar.

2. Pretest Event, 9-11 September 1986. During this event two AE-2s and two AE-3s (three of four with more than 1 year of experience on the F-14A) performed the maintenance tasks planned for the actual field tests. As a result of this event, a number of changes were incorporated into the proposed test procedures, and final scheduling and procedures were established.

3. Field Test, 14-24 October 1986. Test and evaluation of technician performance using conventional and experimental (NTIPS) TI. Tasks included Fault Verification, Troubleshooting (Fault Isolation), and Corrective Maintenance.

1.5 CONDUCT OF THE TEST EVENTS BY ENLISTED TECHNICIANS

Subjects for the test consisted of 24 enlisted technicians, 12 experienced and 12 inexperienced. After an instruction session, each technician performed a troubleshooting task followed by a corrective-maintenance task, under observation by test personnel and by a senior instructor from the FRAMP. The work of each subject was ordered so that he used TI of two different types (e.g., troubleshooting by FIND followed by conventional paper TI for corrective maintenance, as shown later in greater detail by Fig. 1). Performance times (broken down by individual actions) and performance errors for each type of TI tested were recorded. After the test, preference questionnaires were filled out by each technician, and an oral debrief was conducted to elicit comments and suggested improvements for TI constructions and presentation. These results are all detailed in the present report.

1.6 SUMMARY OF TEST RESULTS

All test objectives were accomplished. Carefully monitored technician performance using NTIPS TI covering several types of tasks, with both electronic-delivery and paper presentation, showed the following results:

1. For troubleshooting tasks. Inexperienced technicians achieved a slightly lower overall performance time (8%) using FIND (NTIPS troubleshooting TI, electronically presented) than when using conventional paper-based work-package TM's. Experienced technicians took significantly longer (37%) to accomplish troubleshooting tasks with FIND than with conventional troubleshooting TI.

2. For troubleshooting tasks. All technicians who used FIND successfully isolated the fault without instructor assistance. Of the seven experienced technicians who performed the troubleshooting task using conventional TI, two failed to isolate the fault. Of the five inexperienced technicians who performed the troubleshooting task using conventional TI, all five failed to isolate the fault.

3. For corrective-maintenance tasks. Performance times for all three TI types used (conventional paper, NTIPS paper, and NTIPS electronic presentation) were approximately the same for both experienced and inexperienced technicians. As a group, the inexperienced technicians required slightly more time than experienced technicians when using either conventional paper or NTIPS electronically presented TI.

4. For corrective-maintenance tasks. Inexperienced technicians each committed an average of 8.0 errors when using conventional paper TI. This was reduced to 5.3 errors/technician using NTIPS TI electronically delivered and 5.2 errors/technician using NTIPS TI on paper.

5. For corrective-maintenance tasks. Errors committed by experienced technicians were approximately the same for each type of TI (a range of 3.5-4.0 errors/technician).

6. Of the 20 test personnel who used both electronically presented TI and paper TI, 18 (90%) preferred electronic presentation. Specifically, after the tests, 90% of the test subjects answered the following written question by choosing electronic presentations: If you had a choice of using an electronic or paper-based manual to perform tasks, which would you choose?

1.7 TEST CONCLUSIONS

With the enthusiastic cooperation of COMFITAEWWINGPAC, Squadron VF-124, and enlisted instructors of the FRAMP, the NTIPS field test was carried out successfully. All test objectives were fully achieved. Test results are considered to have demonstrated the following conclusions:

1. Technical information presented electronically represents a distinct improvement in the eyes of fleet technicians engaged in maintenance of operational aircraft. (This result was obtained even with the use of off-the-shelf, non-portable equipment which was not optimally designed for operational use and with graphics which were clearly capable of much improvement.)
2. NTIPS presentations of troubleshooting TI, if carried out according to specifications, can result in significant improvements in fault-isolation effectiveness.
3. The NTIPS presentation methods are effective in improving the performance of inexperienced personnel.
4. Valuable recommendations were provided by test personnel and FRAMP instructors during the tests. For example, it was made clear that the quality of the graphics in any future uses of electronic presentation must be much improved over that of the graphics used in the test. This improvement would involve design of the graphic, graphic size, and graphic resolution. As another example, flexibility must be introduced into the automated TI presentations to permit experienced technicians to move more rapidly through a series of steps without the time-consuming necessity of continually viewing material they already know from experience.

Detailed results of the tests and specific recommendations of the test personnel are discussed in Section 4.0.

1.8 ORGANIZATION OF TEST REPORT

Section 2.0 reviews the preparation and review of the experimental TI (electronic presentation and paper) used for the test and describes the actual tasks selected for testing. Section 3.0 reviews the test design, which was independently published as an

Essex report (cited on page 3). The initial Test Plan was modified to some extent as a result of the Dry Run and of the Pretest Trials discussed previously. These changes are presented in Section 3.0. Section 4.0 discusses in detail the test results and summarizes performance times, performance errors, and other results obtained from observing the test tasks performed by technicians using the five kinds of TI tested. These results include the subjects' preferences and recommendations for improving NTIPS TI and electronic presentation. Section 5.0 consists of a summary of the test operations and conclusions resulting from it. The actual forms used for data collection are incorporated as Appendix A. The preference questionnaire administered to the 24 test subjects is incorporated as Appendix B. Samples of the TI tested are included in Appendix C.

2.0 PREPARATION AND REVIEW OF EXPERIMENTAL AND CONVENTIONAL TI

2.1 INTRODUCTION

This section discusses the generation of the experimental NTIPS TI (2.2), the review of this TI for test suitability (2.3), and the review of conventional TI for compatibility with the NTIPS TI (2.4).

2.2 GENERATION OF EXPERIMENTAL TI

The experimental TI was prepared by Grumman Aerospace Corporation, Bethpage, Long Island, New York. To prepare the TI for test purposes, Grumman was provided with (1) a MODCOMP computer which hosted an automated authoring system developed under the NTIPS Program; (2) an authoring terminal; (3) a screen printer; and (4) a modem which permitted communication with a similar MODCOMP at Hughes Aircraft Company, Long Beach, California for obtaining assistance when problems arose. Grumman personnel were trained by Hughes personnel in operation of the authoring system and in developing system signal-dependency information for the FIND automated troubleshooting program.

NTIPS specifications provided to Grumman for use in preparing the experimental TI included general content, format, and style specifications covering the following TI characteristics:

a. Procedures
b. Descriptive information
c. Illustrations
d. Style (general)
e. Numbering, indexing, and how-to-use information
f. Diagrams.

Also provided was the NTIPS specification entitled "Fault Isolation by Nodal Dependency (FIND): Troubleshooting Equipment, Software, and Products" to permit generation of electronically displayed troubleshooting information.

Before delivery was made to the NTIPS Office, the draft TI was validated with the use of an operational F-14A aircraft at Grumman's Calverton facility on Long Island. Validation consisted of a technical accuracy review by subject matter experts and involved comparing the TI against the aircraft's Rudder Manual Trim System. Reviews to ensure that the experimental TI (both on paper and in electronic-display form) was in compliance with NTIPS specifications for content, format, and style were performed by Grumman, by Hughes Aircraft, by Essex Corporation, and by the NTIPS Office.

Observations made by Grumman during preparation of the experimental TI were recorded in detail in a Journal format (a "Log"), and these data were evaluated to establish the possible need for NTIPS modifications. Certain changes to the NTIPS-designed authoring system, to the electronic-display system, and to the NTIPS TI specification have already been carried out as a result of Grumman's experience. The experience of Grumman Aerospace in applying for the first time the NTIPS TI specifications and in using for the first time the automated authoring system developed under NTIPS constituted in themselves a valuable system test, which demonstrated the technological feasibility of automated preparation of TI of the NTIPS type.

The following experimental TI was generated for the Rudder Manual Trim System (RMTS) tasks:

- A fault-verification procedure. Verification by maintenance technicians of a fault reported by the aircraft crew produces the fault symptoms used for beginning the troubleshooting (fault-isolation) procedure.
- Troubleshooting TI, implemented on the FIND system, used to isolate the faulty component(s) producing an RMTS malfunction (for example, the Directional Trim Actuator, Rudder Surface Position Indicator, or any one of the Pushrods). The only delivery medium for FIND TI is electronic.
- Corrective-maintenance procedure for removal and reinstallation of the Rudder Surface Position Indicator, the Directional Trim Actuator, and the Pushrods. In addition, check and adjustment procedures were provided for the Directional Trim Actuator and any of the Pushrods.
- TI procedures (for both electronic delivery and on paper) for all supporting tasks involved in readying the aircraft for maintenance (such as Connect and Disconnect External Electric Power) and in restoring aircraft to a ready condition. The relevant Illustrated Parts Breakdown (IPB) was also provided.

In accordance with NTIPS procedures, Grumman generated the above experimental TI in a single electronic data base, which was output in both paper and electronic-delivery format by Hughes (under contract to the NTIPS Office) during the mastering process. In the test, one form of the NTIPS test TI was delivered electronically by an AT&T 3B-2/300 computer, using an AT&T 6300 as the subject's interactive terminal. Test subjects entered commands via the 6300's touch screen or keyboard. The display system weighs approximately 40 pounds and has a screen size of 9.5 x 7 inches with a resolution of 640 x

400 lines. This commercial equipment was used to simulate the NTIPS display system for flight-line maintenance which, when fielded, will be a portable device weighing approximately 10 pounds, with dimensions of 12" x 9" x 2", with a screen size of 6.4" x 9.6" and a resolution of 640 lines x 960 lines. The tests were thus designed to test the TI itself and the NTIPS methods of presentation, rather than any hardware device.

Except for FIND troubleshooting TI, the TI described above was provided on paper medium as well as in electronic-delivery form.

2.3 REVIEW OF EXPERIMENTAL TI BY NTIPS OFFICE

The final form of the experimental TI resulted from modifications and corrections based on a detailed review performed by NTIPS Office personnel and other Navy and contractor organizations (Hughes and Essex Corporation). This review was supplemented by a final detailed on-site validation at Miramar Naval Air Station in which the procedures and graphics to be used in the tests were checked in final form by FRAMP instructors against an operational F-14A. Changes suggested as a result of this review were incorporated into the final NTIPS TI. These reviews established that the experimental TI was in accordance with NTIPS Office style, content, and format specifications; verified that the experimental TI contained all information needed by the technicians to perform the tasks used for test purposes; and verified that the established information was accurate and was presented as clearly and simply as possible.

2.4 REVIEW OF CONVENTIONAL TI FOR THE CONTROL TESTS

Conventional TI normally used for F-14A maintenance (that is, relevant work packages of the F-14A Technical Manuals NAVAIR 01-F-14AAA-2-2-16.3, NAVAIR 01-F-14AAA-2-3-4.3, and NAVAIR 01-F-14AAA-2-4-4.1) was used for all troubleshooting and corrective-maintenance RMTS tasks involved in the tests. The NTIPS TI and conventional TI were compared to ensure consistency in the following areas:

- Troubleshooting. The FIND and conventional troubleshooting materials cover the same area of RMTS hardware, i.e., both cover the symptoms and test points for the faulty component. Specifically, in both sets of TI, review ensured that the capability existed to proceed logically from specific trouble symptoms to isolation of the faulty component producing the trouble symptom.
- Corrective maintenance. Both sets of TI cover the same corrective actions (in this case replacement of specified components).

3.0 TEST DESIGN

3.1 Test Personnel

The NTIPS F-14A test was conducted during the period October 14 to October 24 in close coordination with the Fleet Replacement Aviation Maintenance Personnel (FRAMP) organization, VF-124, NAS, Miramar. Actual performance of test tasks took place in the FRAMP maintenance area used for training. This hangar is a short distance from a runway which permits aircraft to be brought in directly from the Miramar NAS squadron areas. A listing of test personnel and their functions is shown in Table 1. Test coordination, subject scheduling, and technical consultation were provided by FRAMP management. Instructor personnel, also from FRAMP, conducted subject test briefings, observed and evaluated subject performance, and served as helpers to subjects when multiperson task performance was required. Twenty-four technicians from squadrons of COMFITAEWWINGPAC participated as test subjects. These subjects performed trouble-shooting and corrective-maintenance tasks as specified in the Test Plan (3.3), responded to a preference questionnaire designed to evaluate the strengths and weaknesses of NTIPS TI as compared to conventional paper work packages, and offered comments during videotaped debriefings.

The test was supervised by a Test Director from DTRC. The functions of the Test Director were to coordinate the test with personnel of NAS, Miramar; to provide technical direction to the test performance; and to ensure that the test was conducted smoothly and on schedule. The Test Director was supported by two data collectors from Essex Corporation, one computer specialist from Hughes Aircraft Corporation, and a video camera crew from DTRC. The data collectors recorded information on subjects' performance time and on the number and type of errors committed during performance of the test tasks, and conducted the debriefings. The Computer Specialist briefed the subjects on the electronic delivery device used and on the NTIPS TI and assisted with the delivery device operation as needed throughout the test. The video-camera crew taped the maintenance-task performance of several subjects and also taped all debriefings. In addition, interviews were taped with instructor personnel who participated in the field test. During these interviews, instructors provided their own assessments of the NTIPS TI, of the test, and of the subjects' performances during the test.

Table 1. Test personnel and functions.

Source of Test Personnel	Function
NAS Miramar (VF-124 FRAMP)	
Management Personnel (Senior Enlisted Instructors)	o Coordinated scheduling of subjects and facilities
Instructor Personnel (Senior Enlisted Instructors)	o Delivered test briefings o Monitored subject-technician performance o Provided assistance to subject-technician in performing multiperson tasks o Provided evaluation of subject-technician performance
Subject Technicians (24) (AEs experienced and inexperienced)	o Performed troubleshooting and corrective maintenance tasks in accordance with conventional paper TI and/or NTIPS electronic/paper TI o Responded to preference questionnaire and post-test briefing (evaluation)
DTRC	
Test Director	o Served as principal NTIPS representative o Directed the test o Coordinated test with NAS Miramar personnel: scheduling, obtaining test subjects, and handling test logistics
Video Camera Crew	o Videotaped maintenance task performance o Videotaped subjects' debriefings o Videotaped interviews with participating FRAMP instructors

Table 1 (Continued)

Source of Test Personnel	Function
Hughes Aircraft Corporation	o Set up and checked out NTIPS TI in both the paper and the electronic delivery media o Briefed test subjects on NTIPS TI and on operation of the electronic delivery device o Assisted in the operation of the electronic delivery device, as needed
Essex Corporation	o Collected data on technician activities, performance times, and errors o Conducted debriefings of subjects and administered preference questionnaires o Analyzed data and prepared test report

3.2 MAINTENANCE TASK DEFINITION

Test subjects performed both troubleshooting (fault isolation) and corrective-maintenance tasks on the F-14A Rudder Manual Trim System (RMTS). The RMTS is part of the Direction Control System of the F-14A aircraft. Specifically, the RMTS affects the yaw-control function by trimming the rudders to compensate for asymmetric flight about the longitudinal axis of the aircraft. The major components of the RMTS are the Pushrods (PR), the Directional Trim Actuator (DTA), and the Rudder-Surface Position Indicator (RSPI). The troubleshooting problem selected for the field test was to find a loose ground wire to the DTA. When the ground was disconnected, the DTA could not be activated by the rudder trim switch and the rudders did not move. This fault was inserted by a FRAMP instructor at the beginning of each test run. To start the test sequence, the subject was given a VIDS/MAF form, prepared by the workshop chief, indicating that the rudder trim was inoperable. The subject then proceeded to verify the fault and to perform appropriate tests to isolate the faulty component.

The corrective-maintenance tasks selected for the test included the removal and reinstallation of the DTA, zeroing and attaching the rudder protractor, and checking and adjusting the rudders. The following criteria were used in selecting these tasks:

- o Tasks must be capable of being performed in an operational environment represented by the maintenance facilities available at a Naval Air Station, with no augmentation of any kind.
- o Tasks must be presented to the technician in a way that conforms to procedures and methods normally used in an operational setting.
- o Tasks must be capable of being performed by the type of technicians called for and available in typical operational maintenance activities.
- o Performance of the task must not require support effort (e.g., rigging) for which NTIPS TI is not available, nor should it require procedures which could have an adverse effect on the operational availability of the aircraft (e.g., interruption of a hydraulic line).
- o A task should be neither too simple nor too complex. The former would have provided inconclusive results, and the latter would have required too lengthy an overall test schedule.

Both the troubleshooting and the corrective-maintenance tasks selected for the tests were representative of maintenance tasks regularly performed on the F-14A. Table 2 identifies each test task selected and shows its position in a typical maintenance sequence carried out at a Naval Air Station.

TABLE 2. Identification and definition of troubleshooting and corrective-maintenance tasks.

	Task Title	Task Definitions
1.	Ready Aircraft for Troubleshooting and Corrective Maintenance	Before any maintenance work can be done, certain safety, power, and system conditions must be set. This task establishes these conditions.
2.	Verify the Fault - Check Rudder Operation with Pedals - Check Rudder Operation with Directional Trim Switch	A (VIDS/MAF) form is used to indicate to the technician which system or subsystem may be causing problems. The technician selects the relevant TI and follows its instructions to verify that the reported malfunction does in fact exist. (In this test, a fault was inserted in an operational aircraft by a FRAMP instructor to ensure a realistic procedure.) Fault symptoms resulting from fault verification serve as the basis for entering the FIND automated troubleshooting system or the troubleshooting part of the conventional Technical Manual.
3.	Troubleshoot to Isolate Faulty Component - Locate Plug Connected to DTA - Test Appropriate Pins	In this task, the technician follows the troubleshooting TI to identify the component causing the fault symptom; i.e., to perform fault isolation. For the NTIPS TI, these step-by-step troubleshooting instructions are called FIND (Fault Isolation by Nodal Dependency). The technician obtains these instructions by interacting with the NTIPS electronic delivery device.
4.	Remove Faulty Component	The technician begins the process of correcting the malfunction by removing the component which his testing has identified as faulty.

Table 2 (Continued)

	Task Title	Task Definitions
5.	Install a New Component	After obtaining a working component from Supply, the technician installs it in the system in place of the faulty component he has removed.
6.	Conduct Operational Check - Attach Rudder Protractor - Check and Adjust Rudder Positioning	The technician performs an operational check of the aircraft to verify that the preceding actions (1) have eliminated the malfunction and (2) have not introduced a new fault into the aircraft.
7.	Restore the Aircraft to Operational Condition	The technician restores the aircraft to operational readiness by eliminating conditions which were changed to permit maintenance, e.g., Reset Switches. Restoration to full operational readiness will be verified by a senior instructor.
8.	Complete Maintenance Records	The technician reports the completed work on the appropriate maintenance action forms; e.g., VIDS/MAF form.

Note: Experimental (NTIPS) TI and conventional TI were provided for all eight tasks. To ensure technician and aircraft safety, Task 1 was performed by senior FRAMP personnel. Tasks 2 and 3 constituted the Troubleshooting Tests. Tasks 4-7 constituted the Corrective-Maintenance Tasks.

3.3 TEST PLANS AND SUBJECTS

The test was designed so that comparisons could be made on a technician's performance using each type of TI. Five task/TI combinations were compared in the field test:

- o Troubleshooting using FIND (NTIPS - Electronic)
- o Troubleshooting using conventional paper TI
- o Corrective maintenance using NTIPS TI in electronic form
- o Corrective maintenance using NTIPS TI in paper form
- o Corrective maintenance using conventional paper work-package TM's.

Each subject performed the troubleshooting task in accordance with only one TI type, and the corrective-maintenance task with a different TI type. Subjects using FIND for troubleshooting used conventional paper TI or NTIPS paper TI for corrective maintenance. Subjects using conventional paper TM's for troubleshooting used NTIPS electronic TI or NTIPS paper TI for corrective maintenance. Subjects were divided into equal groups, with one half performing troubleshooting with each type of troubleshooting TI and one third performing corrective maintenance with each type of corrective-maintenance TI. Additionally, subjects were assigned to two groups based on the amount of their F-14A experience; each of these contained 12 Aviation Electrician's Mates (AEs).

This test design is shown in Fig. 1, which is reproduced from the Test Plan. As the test progressed, some modifications were made to the Test Plan based on the availability of subjects. As a result, the field test, as actually performed, involved 13 experienced technicians and 11 inexperienced technicians. For troubleshooting, half used FIND and half used conventional paper TI; for corrective maintenance, 8 used NTIPS electronic TI, 10 used NTIPS paper TI, and 6 used conventional paper TI. Fig. 2 shows the actual test configurations used, including the number of experience (E) and inexperienced (I) technicians used in each case.

Subjects were classified as experienced (E) if they had one year or more of relevant F-14A maintenance experience and if the Maintenance Chief in VF-124 FRAMP judged that this experience in specific cases was of good quality. The quality of this F-14A experience was carefully weighed in assigning technicians to the E or I category. In two cases, technicians (both E-4s) with slightly more than a year of F-14A experience were nevertheless categorized as inexperienced, and one E-6 (AE-1) with more than 21 years in the Navy, two of those years involving administrative aspects of F-14A maintenance, was classified as inexperienced. No technician in the E class had less than one year of F-14A

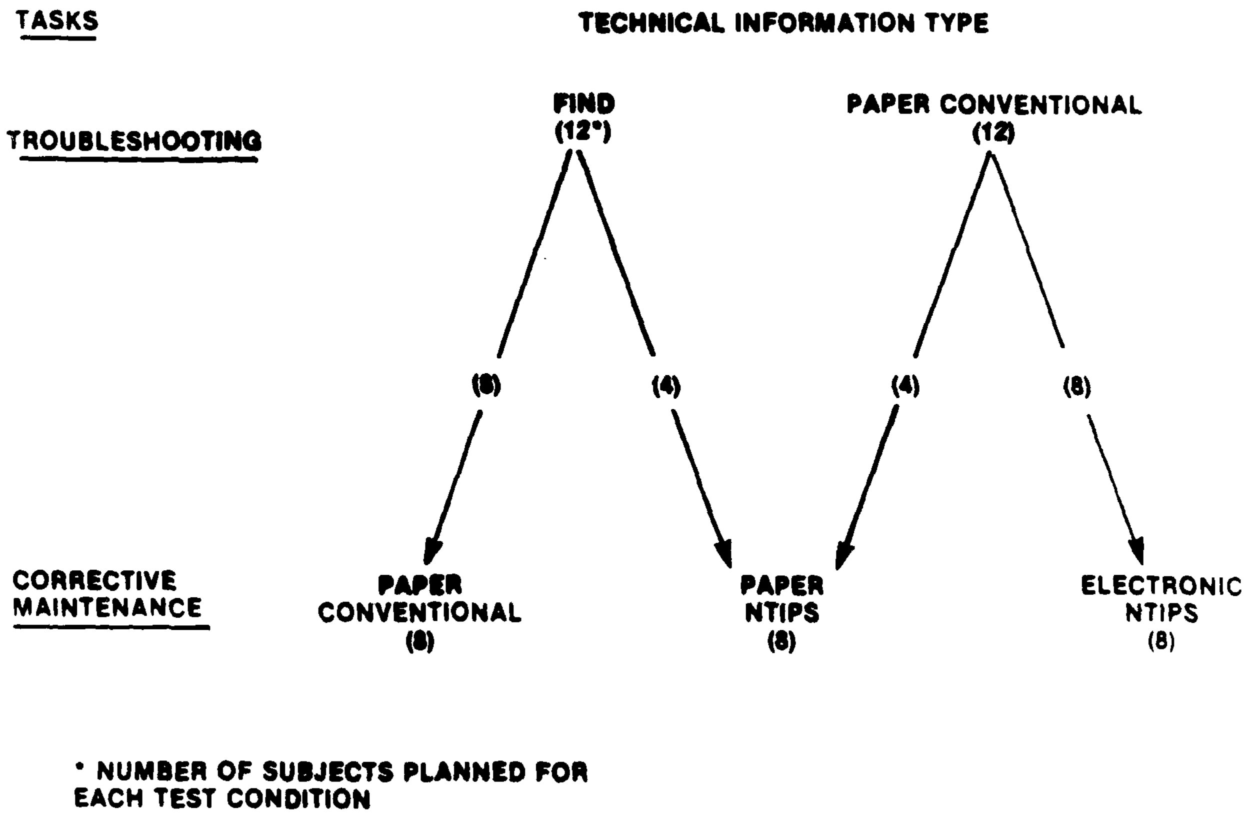
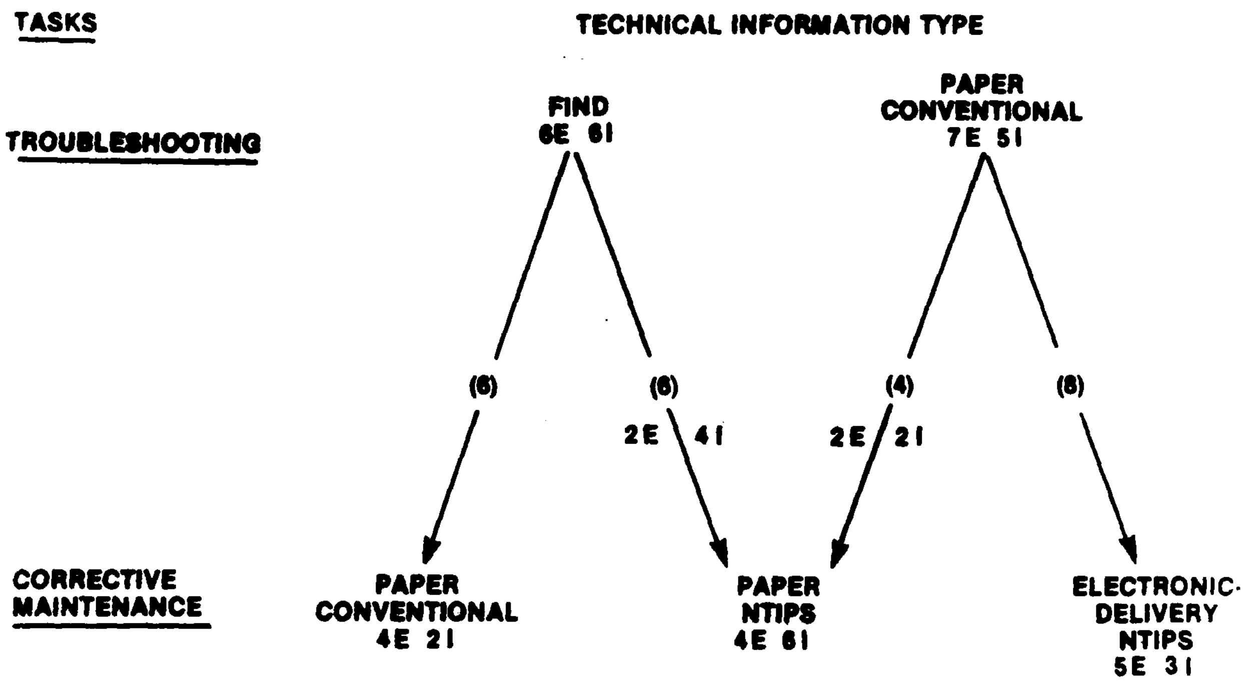


Figure 1. Test plan design.



NOTE: E MEANS EXPERIENCED, I MEANS INEXPERIENCED, (i.e., 6E MEANS SIX EXPERIENCED TECHNICIANS).

Figure 2. Performance of test tasks by technicians during field test.

hands-on maintenance experience. Inexperienced technicians (I) were included in the test to uncover specific problems of clarity in NTIPS presentations of graphics and text. Table 3 lists all subjects and their backgrounds. Of specific interest were:

- o Rate
- o Time in the Navy
- o Time spent performing maintenance on the F-14A
- o Type of maintenance experience
- o Amount of computer experience.

A technician's computer experience was considered important because of its possible influence on his acceptance of or ability to achieve familiarity with the electronic delivery device and on his assessment of its usability and usefulness.

3.4 DRY RUN AND PRETEST EVENTS

3.4.1 The Dry Run

Test personnel conducted an initial walkthrough of the test procedures on 2 May 1986 under the observation of FRAMP instructors. The following test parameters were assessed:

a. Obtain a preliminary evaluation, by senior maintenance personnel, of the experimental TI in terms of test suitability.

b. Work out the interrelationships between test subjects, the personnel recording test data, and the FRAMP instructor serving as test observer.

c. Establish physical locations for equipment, aircraft, delivery devices, and other test-support items.

d. Safety considerations.

A number of changes in proposed procedures and in the actual TI were made as a result of the dry run.

3.4.2 The Pretest Event

During the period 9-11 September 1986, two AE-3s and two AE-2s performed the maintenance tasks planned for the test. These efforts were carefully observed by test personnel and by FRAMP instructors to make sure that the refined test plan was optimal for (1) efficient use of test subjects and observer personnel, (2) safe conduct of the tests, and (3) achieving the test objectives. The results of this pretest event were formally

Table 3. Biographical data for test subjects.

Inexperienced Subjects

Rate	Time in Navy	Time with F-14A	Maintenance Level	Computer Proficiency
E-4	2 yr, 1 mo	1 yr, 4 mo	O	No
E-6	12 yr	7 mo	O	Some
E-3	1 yr, 5 mo	4 mo	O	No
E-6	21 yr, 6 mo	2 yr*	O	No
E-5	3 yr, 1 mo	6 mo	O	No
E-3	1 yr, 10 mo	10 mo	O	Some
E-4	2 yr, 2 mo	1 yr, 2 mo	O	No
E-3	1 yr, 10 mo	7 mo	O	Some
E-3	1 yr, 10 mo	8 mo	O	Yes
E-4	1 yr, 10 mo	7 mo	O	No
E-4	1 yr, 10 mo	3 mo	O	No

Experienced Subjects

Rate	Time in Navy	Time with F-14A	Maintenance Level	Computer Proficiency
E-4	3 yr, 6 mo	2 yr, 6 mo	O	No
E-4	2 yr, 5 mo	1 yr, 3 mo	O	Some
E-5	5 yr, 4 mo	1 yr	O	No
E-4	3 yr, 6 mo	2 yr, 6 mo	O	No
E-4	4 yr	3 yr, 9 mo	O	Yes
E-4	2 yr	1 yr, 6 mo	O	Yes
E-5	7 yr, 8 mo	4 yr, 6 mo	O	No
E-6	7 yr	2 yr	O	Yes
E-5	7 yr, 8 mo	7 yr	O	No
E-5	6 yr, 9 mo	1 yr, 10 mo	O	No
E-5	6 yr, 4 mo	5 yr, 4 mo	I/O	Yes
E-4	3 yr, 8 mo	2 yr, 7 mo	O	No
E-4	2 yr, 10 mo	1 yr, 9 mo	O	No.

All technicians were AEs. Thus, E-3 corresponds to AEAN; E-4 to AE-3; E-5 to AE-2; and E-6 to AE-1.
Participating Organizations: NAMTRADET, AIMD, VF-124, VF-114, VF-24, VF-211, VF-213, VF-301, VF-1, VF-154, VF-2, VF-21

O - Organizational, I - Intermediate

*Paperwork in shop.

documented in an NTIPS Report: "Navy Technical Information Presentation Program. Test and Evaluation of the Navy Technical Information Presentation Systems (NTIPS). F-14A Initial Evaluation", by Anne S. Mavor and Theodore J. Post, Essex Corporation, September 1986.

The Pretest event (and the previous Dry Run) thus constituted a verification of the experimental Technical Information, a vital process in the generation of all system-related TI required to ensure the operational suitability (consistency with fleet procedures, technician capability, and operational environment) of the TI.

As a result of the Pretest event,

1. Some final changes were made to the experimental TI
2. Logistic arrangements for test conduct were finalized
3. Final changes to the test procedure were incorporated to increase test efficiency.

For example, during the pretest event, it was observed that time spent in performance of two of the five Corrective-Maintenance Tasks (specifically 4 and 5) were far more dependent on the manual dexterity of the test subjects than on the nature of the TI used, since both of these tasks (remove a Directional Trim Actuator and replace a Directional Trim Actuator) involved connecting and disconnecting parts in a relatively inaccessible area. Consequently the procedure was modified so that the test subject used the TI for these tasks but orally reported to the observers what he would do to the equipment, e.g., touched the part he believed to be involved and orally described how he would perform the step. Performance of Corrective Maintenance Tasks 6 through 8 was carried out as originally planned.

3.5 TEST SCHEDULE AND PERFORMANCE

The field test was conducted during the period from October 14 to October 24, 1986. Two or three subjects performed the test tasks each day. The schedule of events for each subject was as follows:

- o Attend a test briefing presented by an NAS, Miramar, test coordinator. This briefing covered the test purpose, the tasks to be performed, the estimated time required, and the importance to the program of filling out the preference questionnaire and participating in the debriefing.
- o Attend a technical briefing presented by a Hughes Aircraft representative. This briefing covered FIND and the electronic and paper versions of NTIPS for corrective maintenance. As part of this

briefing the subject was given hands-on experience with the TI, the display, the keyboard, and the touch panel.

- Receive a VIDS/MAF form (problem report) leading to the performance of fault verification and troubleshooting using either FIND or conventional paper TI.*
- Perform corrective maintenance with one of the following TI types: NTIPS electronic delivery, NTIPS paper, or conventional paper work package TM.
- Fill out a questionnaire designed to obtain evaluative comments from the test subjects concerning the use of NTIPS TI, delivered by paper or electronically, and traditional paper TI.
- Participate in a debriefing interview to evaluate the various TI forms and media used and their relative effect on the speed and accuracy of task performance. Provide opinions on new TI approaches.

3.6 THE ELECTRONIC DELIVERY DEVICE

The electronic delivery device was an AT&T 3B-2/300 with an AT&T 6300 touch screen and keyboard. A touch screen works by recording a signal when a finger interrupts infrared beams which form a matrix across the front of the screen. When a pair of beams is broken by a finger passing through the matrix, the corresponding point on the screen is identified as being "touched." The computer terminal was hooked up to a printer and to a display repeater terminal (on the deck) that showed the same image as the primary display screen.

During the test, the computer (delivery device) was located on an elevated test stand at the wing root of the F-14A. The aircraft's wings were swept forward. When using the TI delivery device, the technician stood on top of the aircraft in front of the device, reviewed some subset of the TI, and then moved to one of the work sites (also on top of the aircraft). Depending on the subject's approach to the task and the TI, several trips between the computer and the work site could be required. These work sites atop the aircraft were the cockpit, the rudder area, and the access opening to the DTA. Distances from the delivery device were approximately 30 feet, 15 feet, and 10 feet,

* Conventional work-package troubleshooting TI contains both logic-tree procedures and schematic diagrams showing the component relationship and signal flow. The work package did not contain logic tree procedures relevant to the test fault. The relevant schematics for the fault were contained in NAVAIR 01-F14AAA-2-2-16-3, Technical Manual, Organizational Maintenance, Integrated Weapon Systems Functional Diagrams, Navy Model F-14A Aircraft, Change 3, 15 June 1985, Fig. 47. At Miramar NAS, the invariable practice is to perform fault isolation with the schematics rather than the logic-tree diagrams.

respectively. Any screen image could be printed by executing a print command. This capability allowed a subject to make a hard copy and take it with him to the work site.

The repeater screen was located on the deck and could be used by the subject in performing those steps in the maintenance procedure which required performance on the deck. Distances from the repeater to the two work sites involved were both approximately 15 feet. (Note: If electronic delivery is approved for implementation in the Navy, a portable device would be used to take to the equipment to be maintained).

3.7 DATA COLLECTION CATEGORIES AND PROCEDURES

Data collection categories included (a) two performance measures (performance time and errors committed during task performance), (b) one descriptive measure (actions engaged in by technicians during task performance), (c) technician's subjective ratings (poor to excellent) of the quality of the text and graphics composing the TI they used, and (d) technician's preferences for electronic or paper presentation. Sample data-collection forms for corrective-maintenance task performance are provided in Appendix A (the forms used for troubleshooting performance evaluation were essentially identical). The preference questionnaire is provided in Appendix B. One data collection form was used to record the actions engaged in by the subject when performing each step in the procedure and the time occupied by each type of action. The other form was used to record and describe any errors made by the subject. Each of these forms listed the task steps to be performed.

During the test, the subjects' actions during the prosecution of the test tasks were codified as follows:

- TI — Using Technical Information
- C — Communicating with helper
- W — Performing work on the system
- TI/C — Perusing TI and communicating at the same time (back and forth between perusing TI and talking to helper)
- TI/W — Perusing TI and working (actually moving or changing parts) at the same time — back and forth between TI and work
- C/W — Communicating and working at the same time (back and forth between work and communicating with helper)
- TI/E — Perusing TI and examining equipment (back and forth between TI and looking at equipment).

These categories were used in monitoring field test performance to provide a record showing what the subject did to complete each maintenance step. The procedure used was to record each action code while the corresponding action was occurring and to record the elapsed time until the subject went on to another type of action. Timing was initiated at the beginning of each subtask. Thus, within each subtask or step, it was possible to determine the amount of time spent working, communicating, examining, perusing TI, etc.

The errors made by a subject were recorded on a second data collection form. Categories of errors included

- o False Starts: Begins to work on equipment, stops, looks back at TI, and then starts over.
- o Wrong Location: The subject attempts to find a component in a different aircraft location from the location listed in the step description.
- o Wrong Part: The subject uses the wrong part or tool.
- o Helpers: The subject uses helpers when they are not appropriate or does not use helpers when they are appropriate.
- o Other Errors: Errors not covered by the above categories.

Measures of performance time and accuracy were analyzed by subtask, by type of TI used, and by subject experience. The outcomes of these analyses are reported in the Results section (4.0). In addition, a post-test debrief of the test subjects was conducted. This debrief was used to determine the subjects' attitudes (e.g., acceptance or dislike) toward individual types of TI and the presentation media used. By means of a written questionnaire, subjects were asked to express their reactions, for or against, specific TI characteristics, including style, content, format, delivery medium, and, in general, the ease of use of the TI. It is important to assess which TI characteristics caused the intended users to view TI as beneficial and easy to use, or — on the other hand — troublesome and confusing. A negative reaction in this category of data might indicate areas in which improvement could be required before such a system could be introduced into the Navy. The questionnaire used to obtain the users' reactions appears in Appendix B. This questionnaire includes a scale to allow the respondents to report the intensity of their reactions, negative or positive, on a scale of 1 to 5 to the individual TI characteristics. The first sheet of the questionnaire presents the rating scale and provides instructions for its use. The remaining sheets list the TI characteristics and provide spaces for the subjects to mark their responses. The questionnaire contains four sections: Part I deals with Technical Information, Part II with electronic delivery, Part III with comparing electronic delivery and the conventional paper Technical Information, and Part IV with biographical data.

In addition, each subject was interviewed to allow him to express any opinions not covered by the questionnaire. An outline of this interview appears as the last page of Appendix B.

4.0 RESULTS

4.1 SUMMARY OF RESULTS

The objectives of the NTIPS field test were as follows:

- o Compare the performance of enlisted maintenance technicians using TI prepared under NTIPS procedures to the performance of technicians using conventional TI (the paper F-14A Technical Manual).
- o Compare technicians' performance when using (NTIPS) TI printed on paper to performance using (NTIPS) TI presented via an electronic display device.
- o Establish which design characteristics of NTIPS TI are most effective and least effective in an operational situation.
- o Assess user acceptance of the NTIPS modes (medium, content, format, and style) of TI presentation.

In addition, the field test was designed to provide an evaluation of the NTIPS TI and various aspects of the delivery device in such a way as to indicate the need for improvements or modification in either the TI or in the display system; i.e., it was designed to provide "a formative evaluation." The data on subject preference for various aspects of the NTIPS TI and the use of electronic delivery of TI have been analyzed, and the results are reported below. The general findings were that most (90%) of the subjects preferred electronic delivery of TI over conventional-paper TI presentation and they were able to use NTIPS TI to perform more accurately and, in some cases, with greater speed than when conventional paper TI was used. A summary of the favorable comments about NTIPS is as follows:

- o Electronic delivery provides easier access to desired sections of the TI; the technician does not need to look through several volumes of paper. Access can be achieved by one or two keystrokes.
- o FIND was easy to follow and would be most useful for troubleshooting complex or unfamiliar systems.
- o Electronic TI saves space and is easier to update than conventional paper.

A more detailed review of these comments is provided in the section on Preference Data (4.4).

4.2 PERFORMANCE TIMES AND ACTIONS

As noted, several classifications were established for collecting data describing subjects' actions during the task performance; however, two categories, TI perusal (TI) and work performance (W), accounted for most of the performance time. On the basis of this finding, times spent on all other action categories (e.g., communicating, examining the equipment, etc.) were subsequently combined and labeled "miscellaneous (M)" for purposes of analysis. Analyses of the performance times were conducted for troubleshooting and corrective maintenance.

4.2.1 Troubleshooting Performance Times

Troubleshooting was divided into two tasks: fault verification and fault isolation. Half of the 24 subjects performed these tasks with FIND, while the other half used conventional paper Technical Manuals. For the selected troubleshooting task, the conventional paper TM consisted only of schematics. (No troubleshooting trees relevant to the test fault were included in the conventional TM.) When the NTIPS electronic presentation was used, the fault-verification procedure was directed by the display device as a result of inserting specific trouble symptoms and test results. This was not the case with the conventional paper TM. As a result, some of the subjects using the conventional TM went directly into fault isolation, without performing the fault-verification procedure. The FIND sequence of computer-presented questions and technician-presented answers not only verifies the reported problem, but provides the basis for initiating the fault-isolation procedure.

Table 4 compares the performance times for experienced subjects using NTIPS electronically displayed TI (FIND) with those using conventional paper TM for troubleshooting. Comparison of the total task performance times in each case shows that subjects using NTIPS FIND took an average of 10 minutes (37%) longer to find the fault than subjects using conventional schematics. When these totals are broken down into separate activities of TI perusal, work, and miscellaneous, the following pattern emerges:

- For NTIPS FIND, 53% of the total work time is spent in TI perusal (TI)
- For conventional TI, 59% of the total time is spent in Work
- Subjects using FIND spent somewhat less time working (W) (12.3 minutes) than subjects using conventional TM (17.3 minutes).

As noted in Section 3.5, some troubleshooting decision trees are available in the conventional TI work packages. In this test, of the 12 test technicians who performed fault isolation with conventional paper TI, two (one experienced and one inexperienced) started their performance by looking for the logic-tree diagrams as the basis for troubleshooting. (The other ten began with the schematics.) Not being able to find relevant logic diagrams, the two test technicians were directed by the senior enlisted observers to the schematics, which they then used to proceed with fault isolation. The experienced technician located the fault with the schematics. The inexperienced technician did not (nor did any inexperienced technician using conventional TI). As a result of these incidents, test performance times for the involved technicians were increased by 7 minutes and 14 minutes, respectively. If these times were removed from the averages, the new total time for experienced, conventional TI would be 28.1 minutes (Table 4); for inexperienced, conventional TI, the time would be 44.1 minutes (Table 5).

Table 4. Troubleshooting performance times: experienced subjects.
(times in minutes)

	TI Perusal (TI)	Work (W)	Misc.	Total
FIND	21.0	12.3	6.7	40.0
Conventional TI	8.8	17.3	3.2	29.3

These results suggest that FIND made it possible for subjects to perform the work faster; on the other hand, the time spent perusing the TI was 2.4 times longer for FIND than for conventional TI. Observations of subjects using FIND indicated that much of the time spent using the TI was occupied in responding to the computer-based questions involved in fault verification, waiting for images to change, waiting for the machine to respond to test results provided by the technician, and proceeding through the detailed instructions which were provided for each test point. Observations made during the performances indicated a number of ways in which FIND approaches can be streamlined. When this is accomplished, the total time for troubleshooting with the electronic delivery device should be significantly reduced.

The mean performance times for <u>inexperienced</u> subjects using FIND and for those using conventional TM are shown in Table 5. The results show that, for these subjects, FIND shortened overall performance time somewhat (8.1%). That is, subjects using conventional TI for troubleshooting took longer than subjects using FIND. However, none of the inexperienced subjects using the conventional TI found the fault without some assistance from the instructor who was serving as test coordinator; all subjects using FIND located the fault without instructor assistance (see Section 4.3.1). A comparison of time spent on work and TI perusal for inexperienced subjects shows more time spent perusing the TI and less time doing work when FIND is used. This finding is similar to the pattern shown for the experienced subjects. However, the total time spent on troubleshooting using the two types of TI was very nearly equal.

These test results show that experienced technicians using conventional troubleshooting TMs spend a relatively small portion of their troubleshooting time perusing the TI, but that a proceduralized approach like that of FIND forces them to go through the entire TI process and thus increases the TI perusal time significantly (a factor of 2.4). (For inexperienced technicians, there is little difference in the perusal times for the two types of TI.) To what extent greater familiarity with FIND on the part of the experienced technicians and accomplishment of clearly indicated improvements in the FIND presentation process will reduce this TI perusal time remains to be seen. Further evaluation is required to assess the significance of the result that work time was reduced by use of FIND for both experienced (28.8%) and inexperienced (36.6%) technicians.

Table 5. Troubleshooting performance times: inexperienced subjects.
(times in minutes)

	TI Use	Work	Misc.	Total
FIND	22.4	12.8	7.7	42.9
Conventional TI	20.5	20.1	6.1	46.7

In a further analysis of the troubleshooting performance data, work activities were broken down into specific steps. After a review of the TI, the first step was to remove the access cover so that work could be performed on the DTA. This step was followed by finding the plug and then by testing voltages on the pins. When conventional TI was used, the test subject generally reviewed the appropriate schematic, noted on a scrap of paper the test points he believed to be relevant , and then began the work. With FIND, the subject accessed the electronically presented TI to obtain the procedures for gaining access to the plug, testing the pins, and interpreting the test outcomes.

Figure 3 shows the time used by experienced and inexperienced subjects to get to each point in the task sequence. It can be seen that fault verification always takes longer with FIND than with conventional TI, because the electronic system proceeds in a methodical manner, presenting one question at a time and requiring an answer before the technician can move on to the next question. Time is required to move from one image to the next, and in some cases the subjects became confused as to where they were in the fault-verification process. For the test case, 16 questions were posed. The answers to these questions provided the initial input (trouble symptoms) to FIND.

In the fault-isolation portion of the task process, all subjects removed the cover and found the connector plug faster when using FIND than when using conventional paper (for experienced technicians 12 vs. 18 minutes; for inexperienced technicians 15 vs. 32 minutes). FIND presents detailed instructions with graphics showing the location of the access cover and the DTA. Several of the subjects using conventional TI had difficulty locating the DTA and the connector plug, particularly the inexperienced subjects.

Testing time with FIND took significantly longer than the testing time with conventional TMs. Specifically, experienced subjects took 16 minutes to perform tests with FIND and 7 minutes with conventional TM; inexperienced subjects took 15 minutes and 8 minutes, respectively. Reducing the time required to interact with the FIND program would make the relative times required more nearly equal.

Finally, all subjects using FIND were able to isolate the fault successfully, whereas, 30 percent of the experienced subjects and none of the inexperienced subjects found the fault without assistance.

4.2.2 Corrective-Maintenance Performance Times

Corrective-maintenance consisted of the following tasks:

- o Remove DTA (locate component and describe removal steps)
- o Install DTA (describe installation steps)
- o Zero Rudder Protractor —perform
- o Attach Rudder Protractor — perform
- o Check and adjust rudder positioning — perform

Data on overall performance time and time spent in each type of action were summarized for each subject by task. A post-test review of these data suggested that action-time data be presented in three categories — TI perusal, work, and miscellaneous. Further, the individual performance-time results were averaged across tasks and across subjects.

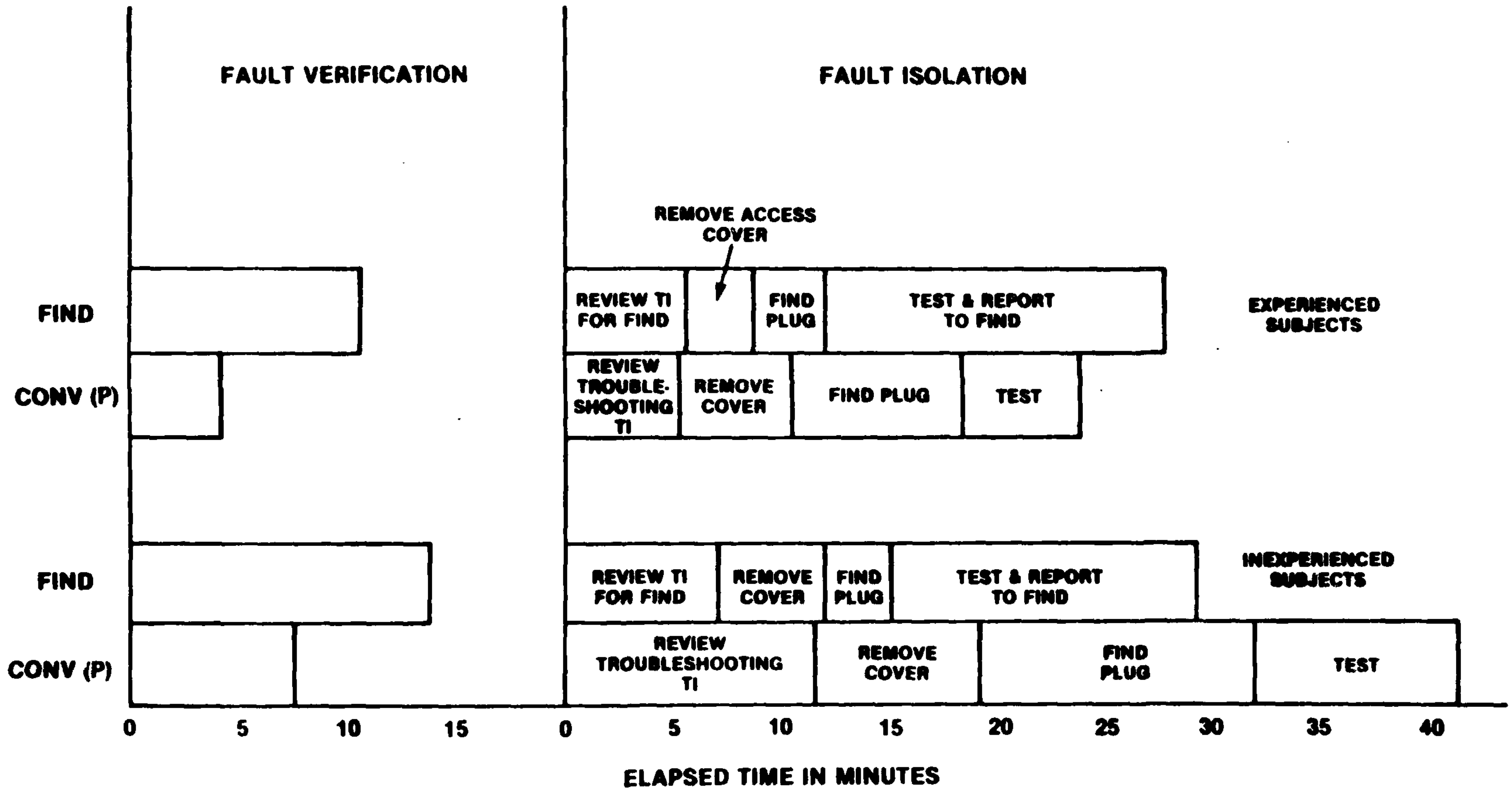


Figure 3. Troubleshooting steps and elapsed time.

The results are shown in Table 6. This table compares mean performance time in minutes for experienced and inexperienced subjects using each of the three types of TI. There is a wide range in the time spent by individual subjects in performing tasks within any given category of TI use. As a specific example, one inexperienced subject working with NTIPS electronic took three times as long as any other subject to perform Check and Adjust. This technician's recent experience involved paper work rather than performing maintenance tasks. His performance time alone is responsible for the increased work time shown for the NTIPS electronic-delivery tests (42.62 minutes) for inexperienced subjects. If his time is removed, the average work time in this test condition would be reduced to 33 minutes — more in line with that obtained using the other types of TI.

The TI perusal time for both experienced and inexperienced subjects is slightly higher for NTIPS electronic-delivery TI than for the other TI categories. Observations of subjects' behavior at the work site suggest two reasons for this result. First, the electronic delivery device was located several feet from the worksite. This required the subject to walk back and forth to read the TI and then perform the work. In many cases the subject returned to the display two or more times to check his memory for the next step. When the paper TI was used, the subject had only to glance down quickly to find his place. (A portable TI delivery device, of the type contemplated by NTIPS instead of the commercial computer used in the tests, would of course eliminate this condition.) The second reason was that the graphics on the electronic display were not as clear and detailed as the graphics in both types of paper TI. As a result, subjects spent more time studying the graphics on the display. This was particularly true for the steps involved in zeroing and attaching the rudder protractor. Almost all the subjects using NTIPS electronic TI exhibited confusion when using the graphics to identify various screws, nuts, and knobs. The tests clearly indicated the need for higher quality graphics than those incorporated into the experimental TI, specifically in terms of fidelity and resolution. There was very little difference in the amount of time spent perusing the TI (in any of the three categories) by experienced and inexperienced subjects.

4.3 PERFORMANCE ERRORS

Performance errors were analyzed separately for troubleshooting and corrective maintenance. The most significant errors in troubleshooting were those involving a failure to isolate the fault. In corrective maintenance, there were no failures to complete tasks, but there were some incorrectly performed steps and inaccurate identifications of parts or part locations. These errors were generally corrected by the subject before

TABLE 6. Corrective-maintenance performance times.

Mean time (minutes)

Experienced Subjects

	TI Perusal	Work	Misc.	Total
Conventional TI	17.8	32.3	3.1	53.2
NTIPS Paper	19.1	36.9	6.5	62.5
NTIPS Electronic	22.7	30.9	6.1	59.8

Inexperienced Subjects

	TI Perusal	Work	Misc.	Total
Conventional TI	20.1	26.7	15.7	62.5
NTIPS Paper	17.1	28.7	13.4	59.2
NTIPS Electronic	25.8	42.6*	9.2	77.6*

*If the test subject whose experience included mostly paperwork is factored out, the work time using NTIPS electronic is reduced to 33 minutes and total time to 68 minutes.

proceeding to the next step. Specific results for troubleshooting and corrective-maintenance errors are discussed in the following sections.

4.3.1 Troubleshooting Error Analysis

The errors committed by subjects while performing fault verification and fault isolation are shown in Table 7. Only FIND subjects made fault verification errors; the absence of errors for this task when conventional paper was used may be attributed to the lack of formal fault verification procedures in the conventional TM. Errors with FIND consisted of answering the fault verification questions incorrectly. These errors were in fact always corrected when the technicians were instructed by the computer to verify their responses.

Table 7. Troubleshooting errors.

	FIND		Conventional Paper	
	Experienced	Inexperienced	Experienced	Inexperienced
Fault Verification	1	3		
Fault Isolation				
- Identified wrong panel			1	4
- Identified wrong plug				5
- Used DC instead of AC		1		
- Forgot to move trim switch	2	1	1	1
- Failed to isolate the fault			2	5
Totals	3	5	4	15

For fault isolation, most of the errors were committed by inexperienced subjects using conventional TI. These errors were in two categories: identifying the wrong access panel and identifying the wrong connector plug.

It is considered important that <u>all</u> of the inexperienced subjects and 28.6 percent (two out of seven) of the experienced subjects failed to find the fault without assistance when using the conventional TM. All subjects using FIND isolated the fault correctly without instructor assistance. These results are summarized in Table 8.

Table 8. Summary of fault-isolation performance.

	FIND			Conventional TM		
Subjects	Successfully Isolated Fault	Number of Subjects	Percent Successful	Successfully Isolated Fault	Number of Subjects	Percent Successful
Inexperienced	6	6	100	0	5	0
Experienced	6	6	100	5	7	71.4
Total	12	12	100	5	12	41.7

4.3.2 Corrective-Maintenance Error Analysis

Tables 9, 10, and 11 show the distribution of errors for corrective-maintenance tasks for inexperienced subjects, experienced subjects, and all subjects, respectively. The results for inexperienced subjects (Table 9) indicate a mean of 8 errors per subject for those using conventional paper TI, as compared with 5.3 and 5.2 errors per subject, respectively, for NTIPS electronic-delivery and NTIPS paper TI. Thus, for this test, there was a 35% reduction in the number of errors in corrective-maintenance task performance using the NTIPS presentation approaches. The small number of subjects in each group makes it difficult to generalize conclusions from these data in any quantitative sense. For experienced subjects (Table 10), there were no significant differences in results for the different types of TI; the range in mean performance errors per subject was 3.5 to 4.0. When errors were combined for all subjects (Table 11), the range in mean performance errors per subject was 4.5 for NTIPS electronic to 5.2 for conventional paper.

Figure 4 shows the distribution of errors for each TI condition. The bars represent the percentage of total errors for each type of TI attributable to a given error category. The major findings are as follows:

- o The largest percentage of errors for NTIPS electronic and NTIPS paper TI is associated with performing a step incorrectly.

Table 9. Corrective-maintenance errors: inexperienced subjects.

		NTIPS(E)	NTIPS(P)	CONV(P)
Remove and Reinstall DTA	Missed step			
	Performed step incorrectly	1		
	Looked in wrong location			1
	Identified part incorrectly	2	3	
	Went to wrong section of TI	1		
Install Rudder Protractor	Missed step		1	2
	Performed step incorrectly	2	4	1
	Looked in wrong location	4	5	3
	Identified part incorrectly	1	6	
	Went to wrong section of TI			1
Check and Adjust Rudder Trim	Missed step			
	Performed step incorrectly	4	7	3
	Looked in wrong location	1	3	2
	Identified part incorrectly			1
	Went to wrong section of TI		2	2
	Total	16	31	16
	Number of subjects	3	6	2
	Mean errors/subject	5.3	5.2	8.0

Table 10. Corrective-maintenance errors: experienced subjects.

		NTIPS(E)	NTIPS(P)	Conv(P)
Remove and Reinstall DTA	Missed step			
	Performed step incorrectly		2	
	Looked in wrong location			
	Identified part incorrectly		2	
	Went to wrong section of TI	1		
Install Rudder Protractor	Missed step			
	Performed step incorrectly	2	1	
	Looked in wrong location	4		5
	Identified part incorrectly	4	3	4
	Went to wrong section of TI			
Check and Adjust Rudder Trim	Missed step		1	
	Performed step incorrectly	6	4	1
	Looked in wrong location		1	1
	Identified part incorrectly	3		1
	Went to wrong section of TI			3
	Total	20	14	15
	Number of subjects	5	4	4
	Mean errors/subject	4.0	3.5	3.75

Table 11. Corrective-maintenance errors: combined for all subjects.

		NTIPS(E)	NTIPS(P)	CONV(P)
Remove and Reinstall DTA	Missed step			
	Performed step incorrectly	1	2	
	Looked in wrong location			1
	Identified part incorrectly	2	5	
	Went to wrong section of TI	2		
Install Rudder Protractor	Missed step		1	2
	Performed step incorrectly	4	5	1
	Looked in wrong location	8	5	8
	Identified part incorrectly	5	9	4
	Went to wrong section of TI			1
Check and Adjust Rudder Trim	Missed step		1	-
	Performed step incorrectly	10	11	4
	Looked in wrong location	1	4	3
	Identified part incorrectly	3		2
	Went to wrong section of TI		2	5
	Total	36	45	31
	Number of subjects	8	10	6
	Mean errors/subjects	4.5	4.5	5.2

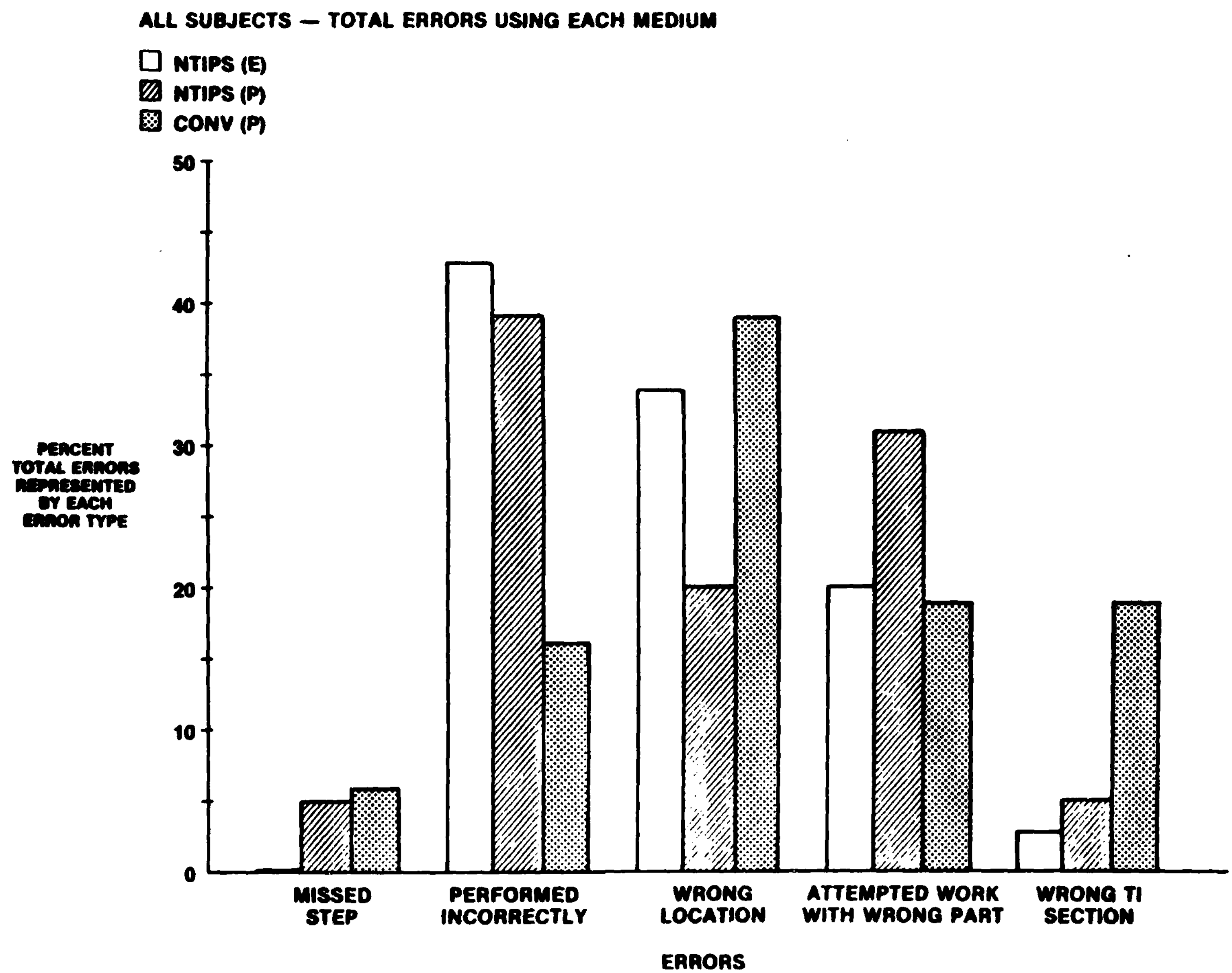


Figure 4. Corrective maintenance errors.

- The largest percentage of errors for conventional paper TI is associated with looking for a part in the wrong location of the RMTS.
- Most of the errors occurred in three categories — performed a step incorrectly, looked for a part in the wrong location in the RMTS, and attempted to perform the work on the wrong part.
- Conventional paper TI showed the highest percentage of errors related to losing one's place in the TI and going to the wrong section.

Most of the errors in step performance were associated with checking and adjusting the rudder trim. Specifically, these errors occurred while the subject was following the instructions to compare the degrees of rudder-trim left and right and then moving to the proper one of two possible steps depending on the result; i.e., branching based on observed rudder movement. It appears that the NTIPS TI, as presented, was more difficult to follow through this sequence than was the conventional TI. In the other major performance task, installing the rudder protractor, the greatest number of errors was in going to the wrong location for attaching the protractor to the rudder and in identifying parts incorrectly. Observations of subjects performing these tasks led to the conclusion that neither the graphic nor the text TI clearly identified the parts of the protractor.

4.4 PREFERENCE DATA AND TI EVALUATION

A preference questionnaire (Appendix B) was completed by all subjects. The subjects were instructed to express a preference as to paper TI or TI delivered electronically and to rate features of the TI and the electronic delivery device on a scale from 1 to 5, with 1 being poor and 5 being excellent. The categories in the questionnaire are as follows:

- Troubleshooting
  - Fault verification
  - Test instructions
  - Graphics
  - RMTS Diagrams (did not use in test)
- Corrective Maintenance
  - Introductory discussion
  - Set-up instructions
  - General safety instructions
  - Step instructions (text and graphics)
  - Support TI
- Electronic System Features
  - Keyboard features
  - Touch screen features
  - Screen display features (brightness, readability, etc.)
  - Procedures for moving through TI.

Questions presented to elicit an expression of preference for electronic delivery or for paper TI delivery were as follows:

1. If you had a choice of using an electronic or paper-based manual to perform tasks, which would you choose? ______________________

2. In working with the technical documentation, was it easier with the electronic device? ______________ Or paper? ______________

3. Which mode of presentation was better organized for your purposes? Electronic? ______________ Or paper? ______________

Table 12 summarizes the responses to these questions, broken down by experience level of the technicians. As may be seen from Fig. 2 (Section 3), 20 of the 24 test subjects performed tests with a form of electronically delivered TI: They either used FIND or they used corrective maintenance TI that was electronically delivered.

Table 12. Subjects' preference for TI medium: paper or electronic delivery.

	Experienced		Inexperienced		Total	
	Paper	Electronic	Paper	Electronic	Paper	Electronic
Question 1	1	10	1	8	2	18
Question 2	2	9	1	8	3	17
Question 3	1	10	2	7	3	17

Of the entire population of test subjects, 90 percent preferred electronic display to paper TI based on their recent experience with it. Of the total group 85% considered the TI they had used to have been better organized and easier to use in electronic form than in paper form. It is noted that these evaluations were made in spite of the fact that the hardware used to present the TI electronically was far from optimally designed for flight-line maintenance and the fact that the technicians recognized a number of specific defects in the TI itself (e.g., graphics quality and presentation sequence in FIND).

The subjects' responses to the questionnaire were summarized by groups based on the TI types used in the field test. Table 13 shows the mean ratings for troubleshooting TI by subjects using FIND as compared to ratings by subjects using conventional paper TI. The following points can be made from this table:

- For the actual presentation of text and graphics, inexperienced subjects rated conventional paper TI somewhat higher than FIND; they were least satisfied with the graphics included in FIND (an average rating of 3.1).
- Experienced subjects rated the text and graphics presentations of FIND higher than that of conventional paper; they were least satisfied with the text in the conventional TI (an average rating of 2.2).

The text and graphics in FIND provided detailed step-by-step instructions for identifying and removing the access cover, locating the connector plug, and performing the selected tests. Inexperienced subjects found it more difficult to read and follow the graphics than did the experienced subjects. Table 14 shows the characteristics of FIND that were liked most and least by each subject group. Essentially, the inexperienced group liked the step-by-step instructions and the organization of procedure best, while the experienced group found these characteristics to be the least desirable. Observations of troubleshooting performance suggest that experienced subjects were slowed down by the FIND procedure of sequentially presenting one test or check at a time; this was not the case for inexperienced subjects. Approximately one-third of all subjects considered that FIND would be most useful for complex or unfamiliar troubleshooting problems. On the other hand, the procedural nature of FIND takes the technician out of any real decision-making role in the problem-solving process — it does not provide the conceptual framework for understanding and interpreting the troubleshooting problem but converts it to a routine sequential procedure for which it provides detailed direction. Obviously such an approach would appeal more to inexperienced technicians than to experienced technicians who consider that they are very familiar with the system involved.

Table 13. Troubleshooting TI.
(Mean preference ratings on a scale of 1 (poor) to 5 (excellent))

	FIND		Conventional Paper	
	Experienced	Inexperienced	Experienced	Inexperienced
Text Quality	3.9	4.2	2.2	4.5
Graphics Quality	4.1	3.1	3.6	4.4

Table 14. FIND characteristics and subject preferences.

	Experienced	Inexperienced
Most liked	- Touch screen	- Step by step procedures
	- Menus	- Organization (order) of procedure
Least liked	- Step by step procedures	- Graphics quality (detail)
	- Organization (order) of procedure	- System response time

Table 15 shows the subjects' ratings for the three types of corrective-maintenance TI. These ratings range from 2.9 - 3.0 to 4.5, with the lowest ratings given to graphics in NTIPS paper TI (2.9) and NTIPS electronic-delivery TI (3.0) and the highest to text in NTIPS electronic (4.5). For the most part, the text of procedural steps was rated higher for NTIPS TI than for conventional paper TI.

Table 15. Corrective maintenance TI.
(Mean preference ratings on a scale of 1 to 5 (poor to excellent))

Instruction	NTIPS(E)		NTIPS(P)		CONV(P)	
	E	I	E	I	E	I
Set up	3.8	4.1	3.9	3.4	3.9	3.3
Steps (Text)	4.2	4.5	4.3	3.7	3.3	3.9
Graphics	3.0	4.1	3.8	2.9	3.5	3.8

Table 16 shows subjects' selection of NTIPS electronic-delivery characteristics that were the most and least effective in assisting the corrective-maintenance process. All subjects agreed that size and detail of graphics were the least attractive features. The features selected as most desirable were the touch screen, the size of the text, the availability of a screen printer, and the ability to move around in the data (i.e., flexibility of access to particular pieces of information).

Table 16. NTIPS electronic delivery TI characteristics and subject preferences.

	Experienced	Inexperienced
Most Liked	- Touch screen	- Touch screen
	- Availability of screen printer	- Size of text
	- Ability to move around in data (flexibility of data areas)	
Least Liked	- Size of graphics	- Number of graphics
	- Detail of graphics	- Detail of graphics

In the third section of the questionnaire, subjects rated electronic delivery-system features such as the keyboard, the touch screen, the screen layout, and the menu structure. As shown in Table 17, all the features received high ratings for FIND and for NTIPS electronically delivered corrective-maintenance TI; the range was from 3.5 to 4.6.

Table 17. Electronic delivery system features. (Mean Preference Ratings on a scale of 1 to 5 (poor to excellent))

Features	FIND		NTIPS(E)	
	Experienced	Inexperienced	Experienced	Inexperienced
Keyboard	4.2	4.1	4.5	4.2
Touch screen	3.5	4.2	4.6	4.4
Screen layout	4.2	4.1	4.3	4.1
Menu structure	4.0	4.2	3.9	4.1

Finally, subjects were asked to provide their reasons for preferring electronic delivery of TI and to suggest specific areas for improvement. The most positive comments about *electronic delivery* were that (1) it provides easier access to TI, (2) it saves space, and (3) electronically stored and delivered TI is easier to update. Suggestions for improvement of NTIPS TI included (1) increasing the size and detail of graphics, (2) increasing the size of touch labels, and (3) including caution notes on the same screen with the relevant maintenance step. Table 18 summarizes these comments and shows their frequency from each experience level group.

Table 18. Subjects' comments on acceptability and suggestions for improving electronic delivery of TI.

Comments	Experienced	Inexperienced
Electronic-delivery provides easier access to desired sections	8	5
Electronic-delivery saves space	2	1
Electronic-delivery TI is easier to update	2	-
The touch screen makes the job go faster	1	-
Electronic presentation is good for self teaching	-	1
Graphics are hard to read - should be larger, more detailed	3	2
Graphics should be presented with positive image (black on white)	1	-
Caution notes should appear with step (same screen)	1	-
Touch labels are too close together	1	1
FIND is time consuming	1	1
Total number of comments	20	11
Total number of technicians in class	11	9

5.0 CONCLUSIONS

5.1 INTRODUCTION

The NTIPS test and evaluation was conducted in two stages:

1. The preparation of test TI in accordance with NTIPS specifications and by use of an NTIPS-developed automated authoring system.

2. The comparison of technician performance quality resulting from the use of NTIPS and conventional TI in carrying out maintenance tasks on an F-14A aircraft. Conclusions drawn from the data collected during both stages are presented in the following sections.

5.2 SUMMARY OF CONCLUSIONS

Results of the NTIPS field test have shown that TI constructed by automated authoring and according to NTIPS specifications, when applied by fleet technicians in operational maintenance tasks, can significantly improve performance (particularly troubleshooting). These results also show that the electronic presentation of maintenance TI is considered superior to paper presentation of TI by approximately 90% of experienced and inexperienced technicians.

The tests also provided valuable guidance, both in the area of specifying the most effective TI (e.g., the need for better graphics, better organization, better approaches to presentation) and in the area of electronic-presentation approaches. A number of these suggestions have already been incorporated into NTIPS approaches.

Although it is difficult or impossible to generalize from a test involving a small population of technicians working on a specific maintenance area (an aircraft electromechanical system), it appears there is no fleet objection to the automated generation and presentation of fault-isolation and corrective-maintenance TI. The TI innovations proposed by NTIPS in TI content, format, style, and organization are as effective and in some cases more effective than conventional paper TI.

5.3 CONCLUSIONS REGARDING NTIPS SPECIFICATIONS AND AUTHORING SYSTEM FOR GENERATING TI

In general, the TI contractor was able to follow the NTIPS TI specifications and was also able to use the TI authoring system to prepare the experimental TI presenting F-14A procedures used in the field test. Use of an automated authoring system to prepare Navy weapon system TI in no way reduces the need for a careful contractually mandated quality assurance program. Specific observations recorded during the preparation process are summarized below.

5.3.1 Specifications

No problems were found regarding clarity of specifications. However, test data showed that the contractor experienced consistent problems in carrying out some of the aspects of TI generation required by TI specifications. Since some of the NTIPS approaches to TI generation were entirely new to the TM writers, this was not an unexpected result.

5.3.2 Computer-Assisted Authoring

During the TI generation process, extensive interaction was required between the TI contractor and the developer of the authoring programs due to the radical difference between the automated approach and the manual approach to TI generation with which the contractor was familiar. The prompting feature of the NTIPS automated authoring systems was not particularly effective as designed. The computer used to host the authoring routine has been made obsolete by rapid technological progress in automated authoring.

5.4 CONCLUSIONS AND OBSERVATIONS BASED ON DATA FROM FIELD TEST

This section summarizes the impact of the NTIPS experimental TI on maintenance task performance. This section also summarizes observations made during the operational field test conducted at the Miramar Naval Air Station including

(1) Observations and specific recommendations made by the test subjects concerning their reactions to, and proposals for improvement of, the NTIPS experimental TI and the electronic-delivery methodology.

(2) Observations and recommendations made by test coordination personnel concerning the field use of NTIPS and conventional TI, and proposed methods of improving NTIPS TI and delivery methodology.

Reactions of test subjects to the various TI features were consistent with operational tests made previously by the three services or various kinds of TI content, format, style, medium, and procedural organization. Special relevance of these reactions to improvement of the NTIPS technology (both TI and presentation methodology) is cited in the following section.

5.4.1 Different Approaches to TI Use

Several approaches to the use of TI were observed among technicians during the test. A popular approach involved a complete review of the procedure before any steps were performed, instead of reading each step once and then performing it before moving ahead in the TI. The implication of this observation is the possible benefit which would result from providing a browsing mode in the electronic delivery of task instructions, i.e., providing a summary of a sequence of steps (for example, a kind of annotated checklist) as an alternative to complete details for one step at a time.

5.4.2 Troubleshooting Task Performance Time

For experienced subjects, use of FIND increased total fault isolation time an average of 37%, caused entirely by the necessity to peruse each sequence presented by the FIND screen rather than skimming over a schematic with a speed made possible by experience. Thus, experienced technicians spent 2.4 times longer perusing the FIND TI than the conventional schematic fault-isolation TI. The actual working time (testing, locating, and exposing test points, etc.) was reduced by an average of 28.2% by use of FIND.

For inexperienced technicians, the use of FIND decreased slightly (9.2%) the total fault-isolation time over that resulting from use of conventional TI. (Troubleshooting with conventional TI by inexperienced technicians was, as noted above, entirely unsuccessful.) With FIND, inexperienced technicians completed their tasks in about the same time as did experienced technicians. Inexperienced technicians took 7.3% longer. As in the case of the experienced technicians, actual work-performance time was reduced (by 36.2%) through use of FIND.

5.4.3 Errors in Troubleshooting

The most significant error in fault isolation was a failure to isolate the introduced fault. None of the technicians, experienced or inexperienced, failed to locate the fault using FIND. All inexperienced and 2 of the 7 experienced technicians failed to isolate the fault with conventional fault-isolation (schematic) TI. Occurrence of other types of errors was about the same for troubleshooting by experienced technicans using FIND and using conventional TI; inexperienced technicians committed about twice as many errors (10/5) using conventional TI as using FIND.

5.4.4 Corrective-Maintenance Performance Time

As in the case of the troubleshooting tasks, corrective-maintenance tasks performed with NTIPS TI (both paper and electronically-presented) took experienced technicians somewhat longer than performance with conventional TI (17.6% and 12.6%, respectively). This time increase is ascribed to the poor quality of graphics and, for the subjects using the electronic device, to the need to move back and forth between the device and their work location. Time spent actually perusing the TI was again greater for both types of NTIPS TI than for conventional TI (7.4% and 27.8% for NTIPS paper and electronically-presented TI, respectively). The actual worktime was approximately the same (ranging from 31.0 minutes to 36.9 minutes). On the average, inexperienced technicians took longer to perform their corrective-maintenance tasks using NTIPS electronic TI (and committed fewer errors) than with conventional TI. The relative average total times involved were 77.66 minutes vs. 62.48 minutes, but a significant fraction of the NTIPS electronic result was due to abnormally long work-time of a single technician. If his contribution to the total time for NTIPS electronic TI use was removed, the total performance time for the three types of TI used would be much closer (68.0 minutes for NTIPS electronics, 59.15 minutes NTIPS paper, 62.5 minutes conventional). Breakdowns of corrective-maintenance time among the three components used (TI-perusal, hands-on work, and miscellaneous) did not show significant differences except in the case of the technician referred to above.

5.4.5 Corrective-Maintenance Errors

On the average, inexperienced technicians committed fewer errors per technician with both types of NTIPS TI than with conventional TI in corrective-maintenance tasks (about 35% less). There was little difference in the error rates for experienced technicians among the three types of TI; these rates, as might be expected, were lower for experienced technicians than for inexperienced technicians.

5.4.6 Range in Reading Abilities

Test subjects represented a wide range of reading abilities. Some subjects read aloud, others by following along with their fingers. Reading rates and apparent comprehension varied from fast with good comprehension, to slow with many re-reads. English was the second language for some of the subjects. Implications to TI design of the reading-trait variations observed during the tests are under further study.

5.4.7 Preferences for TI Types

During the troubleshooting tests, those technicians assigned to the conventional TI category were asked to proceed with the task using the method they normally used in carrying out squadron maintenance. Most skipped or abbreviated the fault verification task and many took notes on the relevant portions of the Level 2C troubleshooting schematics of NAVAIR 01-F-14AAA-2-2-16.3. These notes were taken to the job rather than the full (8-1/2" x 34") schematics. During debriefing, a pattern of preference as a function of experience-level became apparent for the technicians in this group. All technicians using conventional TI were familiarized also with the NTIPS FIND method of troubleshooting prior to the test. In spite of the high (90%) preference for electronic delivery expressed by test subjects in answer to direct questions, a number of experienced technicians expressed a preference for the familiar troubleshooting schematics as a troubleshooting approach, while the inexperienced technicians favored the step-by-step procedures of FIND. Previous research on this question has suggested that a proceduralized format such as FIND (do this, then do that) and a decision-making format such as the schematics included in the conventional TI might be integrated, particularly with electronic display. Information might also be added to help the inexperienced technicians transition from the proceduralized to the decision-making format. Further research is needed to determine the best way to handle schematics on an electronic display device.

Both experienced and inexperienced technicians favored the electronic delivery of corrective-maintenance TI. They considered that the electronic delivery was superior to paper because it provides easier access to desired TI sections, saves storage space, and is easier to update.

5.4.8 Communication and Team Performance

The NTIPS TI, for both corrective and troubleshooting tasks, provided only minor guidance for work allocation among the various members of a maintenance team; the setup instructions provided did not detail requirements for communication between and among workers. Safety regulations required that cranial protection, which constrained normal conversation, be worn during aircraft maintenance. Future TI specifications should emphasize (1) the identification of worker responsibility in a task-specific manner and of worker locations, and (2) the need for, and the means of, communication between workers.

5.4.9 Graphics Detail

Many of the graphics in the NTIPS TI (especially the electronic version) showed necessary detail, but with dimensions that were too small to be of greatest benefit to the user. The quality of the graphics was below the quality obtainable by modern state of the art systems. The result was unnecessarily high error rates (looking in the wrong location for a part and identifying the wrong part). High quality graphics are required, both in terms of size and fidelity of detail, for future applications. Ultimately, optimization of text-graphics modules involves trade-offs among such variables as (1) the relationships of text to graphics on a given display, (2) the determination of the ideal amount of work prescribed by the instructions in a single frame, (3) the resolution of the display, (4) the field-of-view of the graphic, and (5) the level of detail provided in the graphic. Rules-of-thumb and conventions based on human factors engineering are available for the treatment of all these variables. Appropriate guidance must be incorporated in a clearly interpretable form in future specifications for automated generation of TI.

5.4.10 Decision-Making Performances

One of the test tasks (Check and Adjust Rudder Trim) required branching; e.g., statements of the following type: "If greater than 7 degrees, go to step x; if less than 7 degrees, go to step y." Observations by data recorders, analysis of time spent by technicians in perusing the TI, and analysis of errors all indicated that technicians had trouble understanding these sections of the TI no matter what the form of presentation. The cause and solution of this problem are not clear. Further analysis leading to improvement of the relevant specifications is necessary to solve this important problem, especially for the electronic delivery of TI.

5.4.11 Electronic-Delivery Device

The device used in the field test was an off-the-shelf (non-militarized) item and since its significance was solely to provide a basis for evaluation of electronically presented TI, reactions to the display device itself received from test subjects are not intrinsically significant. However, some observations were general enough to be useful. For example, the use of powered devices on the aircraft during maintenance is prohibited. If a portable device is to be taken aboard an aircraft as a maintenance tool, this question must be dealt with. Glare, even in a hangar environment, presents a problem; a delivery device must be carefully constructed for optimum TI visibility. Some means of anchoring the device is required (few flat surfaces are available). Additionally, although technicians commented favorably about the concept of the touch, some drawbacks were noted, e.g., the touch labels were too small and too close together.

5.4.12 Paper-Delivery Medium

Deficiencies and problems noted for the electronic-display medium in general apply also to paper. In addition, observations unique to paper include (1) the critical need for a comprehensible and consistent TI numbering system, (2) a means of binding that allows the package to lie flat during use, and (3) a means of packaging sets of task procedures that retains the benefits of smallness and portability.

APPENDIX A:
DATA COLLECTION FORMS

A sample data-collection form for a corrective-maintenance task is included as page 56 (Activity Time) and page 57 (Error). Forms of this type were filled out by test personnel for each subtask of each maintenance task, while the test subject was performing the task.

Filled-out Activity-Time and Errors forms for Task 4-2.5, Install Rudder Protractor Subtask 1: Zero Rudder Protractor (using NTIPS paper) are also incorporated as pp. 58 and 59. The symbols used to describe the individual actions being carried out during task performance are described in Section 3.6.

APPENDIX A
DATA COLLECTION FORMS

A sample data-collection form for a corrective-maintenance task is included as page 57 (Activity Time) and page 58 (Error). Forms of this type were filled out by test personnel for each subtask of each maintenance task, while the test subject was performing the task.

Filled-out Activity-Time and Errors forms for Task 4-2.5, Install Rudder Protractor Subtask 1: Zero Rudder Protractor (using NTIPS paper) are also incorporated as pp. 59 and 60. The symbols used to describe the individual actions being carried out during task performance are described in Section 3.6.

FORM A: ACTIVITY TIME - CORRECTIVE MAINTENANCE

<u>Task 4-2.5</u>: Install Rudder Protractor

<u>Subtask 1</u>: Zero Rudder Protractor

Subject ______________

Date ______________

Step Description								Total Time
1. Attach indexer - ground; helper (1)								
2. Loosen lock nuts - ground; no helper								
3. Adjust screws - ground; no helper								
4. Check indexer (0^{o}) - ground; no helper								
5. Secure adjustment screws - ground; no helper								
6. Loosen attaching screws - grounds; no helper								

FORM B: ERRORS - CORRECTIVE MAINTENANCE

Task 4-2.5: Install Rudder Protractor

Subtask 1: Zero Rudder Protractor

Subject ____________________

Date ____________________

Step Description	False Starts	Wrong Loc	Wrong Part	Helper	Other Errors	Error Description
1. Attach indexer - ground; helper (1)						
2. Loosen lock nuts - ground; no helper						
3. Adjust screws - ground; no helper						
4. Check indexer (0°) - ground; no helper						
5. Secure adjustment screws - ground; no helper						
6. Loosen attaching screws - grounds; no helper						

FORM A: ACTIVITY TIME – CORRECTIVE MAINTENANCE

Task 4-2.5: Install Rudder Protractor

Subtask 1: Zero Rudder Protractor

TYPE OF TI: NTIPS PAPER

Subject ______________

Date ______________

Step Description	Time							
1. Attach indexer – ground; helper (1)	TI .20	Wait tools, etc 2:13	TI 3:00	Q 3:30	E 4:12	C 5:30		
2. Loosen lock nuts – ground; no helper	TI 3:40	W 8:34						
3. Adjust screws – ground; no helper	TI/C 9:50	W/C 10:35	TI 11:00					
4. Check indexer (0°) – ground; no helper	W 13:04	TI 13:12						
5. Secure adjustment screws – ground; no helper	W 14:27							
6. Loosen attaching screws – grounds; no helper	TI 15:00	W 18:36						
	Missed attaching screws							

SAMPLE

FORM B: ERRORS - CORRECTIVE MAINTENANCE

Task 4-2.5: Install Rudder Protractor

Subtask 1: Zero Rudder Protractor

Subject ______________________

Date ______________________

Step Description	False Starts	Wrong Loc	Wrong Part	Helper	Other Errors	Error Description
1. Attach indexes R - ground; helper (1)			✓			Adjustment screws vs attachment
2. Loosen lock nuts - ground; no helper						OK
3. Adjust screws - ground; no helper		✓				Didn't know where [illegible] were
4. Check indexes R (0°) - ground; no helper						OK
5. Secure adjustment screws - ground; no helper						OK
6. Loosen attaching screws - grounds; no helper						OK

SAMPLE

PREFERENCE QUESTIONNAIRE

Instructions for Completing Questionnaire

Now that you have done troubleshooting and corrective maintenance with different forms of technical information (TI), we are interested in your evaluation. First, read the information on this page. Then complete the questionnaires that follow. Be sure to complete every item. Don't leave any items blank.

Your questionnaire responses will not be used to rate your fitness. All of your responses will be kept in total confidence.

Some questionnaire items ask you to rate TI features on a five-point scale from 1 (for Very Poor) to 5 (for Excellent). Use the definitions of the numbers in the scales that are given below to help make your rating decisions.

1 -	VERY POOR	I don't see how the job can be done with this feature the way it is.
2 -	POOR	This feature isn't very good.
3 -	AVERAGE	This feature is O.K.
4 -	GOOD	This feature makes tasks easier/quicker to perform.
5 -	EXCELLENT	This feature is really great.

As you come to the lists of features on the questionnaires, try to remember how much each feature helped or hindered you. Select the rating that corresponds to your judgment, and mark it on the questionnaire.

Use the COMMENTS column at the right of rating scales or at the end of it to note any strong feelings about a feature or to suggest how it might be improved.

Be sure to complete the BIOGRAPHICAL section at the end of the questionnaire.

If you have any questions, ask a data collector for help.

POINTS TO CONSIDER

Please follow the rules listed below when completing the questionnaire.

1. As you come to characteristics on the questionnaire, try to remember how much each characteristic helped or hindered you during your task performance. Select the rating that corresponds to this degree of helpfulness and mark it on the questionnaire.
2. If you have strong feelings about some characteristic of the information you worked with, but this characteristic is not listed on the questionnaire, please describe and rate it (or them) in the comments section.
3. Please complete the administrative section (last page) of the questionnaire. If you have any questions, ask the data collector.

APPENDIX B
PREFERENCE QUESTIONNAIRE

Appendix B contains a sample preference questionnaire filled out following the test by all of the 24 test subjects. Results are analyzed and discussed in Section 4.4. The complete set of executed questionnaires has been retained by the NTIPS Office. Further analyses of these data and those from the videotaped post-test interviews are being carried out to make certain that all possible lessons learned from this field test are applied to future NTIPS designs.

The Preference Questionnaire consists of the following sections

PREFERENCE QUESTIONNAIRE

Instructions for Completing Questionnaire

Now that you have done troubleshooting and corrective maintenance with different forms of technical information (TI), we are interested in your evaluation. First, read the information on this page. Then complete the questionnaires that follow. Be sure to complete every item. Don't leave any items blank.

Your questionnaire responses will not be used to rate your fitness. All of your responses will be kept in total confidence.

Some questionnaire items ask you to rate TI features on a five-point scale from 1 (for Very Poor) to 5 (for Excellent). Use the definitions of the numbers in the scales that are given below to help make your rating decisions.

1 -	VERY POOR	I don't see how the job can be done with this feature the way it is.
2 -	POOR	This feature isn't very good.
3 -	AVERAGE	This feature is O.K.
4 -	GOOD	This feature makes tasks easier/quicker to perform.
5 -	EXCELLENT	This feature is really great.

As you come to the lists of features on the questionnaires, try to remember how much each feature helped or hindered you. Select the rating that corresponds to your judgment, and mark it on the questionnaire.

Use the COMMENTS column at the right of rating scales or at the end of it to note any strong feelings about a feature or to suggest how it might be improved.

Be sure to complete the BIOGRAPHICAL section at the end of the questionnaire.

If you have any questions, ask a data collector for help.

POINTS TO CONSIDER

Please follow the rules listed below when completing the questionnaire.

1. As you come to characteristics on the questionnaire, try to remember how much each characteristic helped or hindered you during your task performance. Select the rating that corresponds to this degree of helpfulness and mark it on the questionnaire.
2. If you have strong feelings about some characteristic of the information you worked with, but this characteristic is not listed on the questionnaire, please describe and rate it (or them) in the comments section.
3. Please complete the administrative section (last page) of the questionnaire. If you have any questions, ask the data collector.

Part I – Technical Information

Information Characteristics	Strength of Approval or Disapproval 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
CORRECTIVE MAINTENANCE TI						
1. Introductory Discussion	____	____	____	____	____	________
2. Setup Instructions						
a. "Applicable Configuration"	____	____	____	____	____	________
b. Test Equipment	____	____	____	____	____	________
c. Tools	____	____	____	____	____	________
d. Materials/Parts List	____	____	____	____	____	________
e. Task References	____	____	____	____	____	________
f. Personnel Required	____	____	____	____	____	________
g. Special Skills and Knowledges	____	____	____	____	____	________
h. Approximate Time Required	____	____	____	____	____	________
i. List of Directives	____	____	____	____	____	________
3. General Safety Instructions	____	____	____	____	____	________
4. Step Instructions						
a. Organization into Tasks, Subtasks, and Steps	____	____	____	____	____	________
b. Amount of text	____	____	____	____	____	________
c. Usability of text						
– Level of Detail	____	____	____	____	____	________
– Format	____	____	____	____	____	________
– Clarity of Writing	____	____	____	____	____	________

Part I (Continued)

Information Characteristics	Strength of Approval or Disapproval 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
CORRECTIVE MAINTENANCE TI						
d. Amount of Graphics	____	____	____	____	____	____
e. Usability of Graphics						
- Legibility	____	____	____	____	____	____
- Understandability	____	____	____	____	____	____
- Size	____	____	____	____	____	____
- Ease in Finding Components	____	____	____	____	____	____
- Level of Detail	____	____	____	____	____	____
- Format	____	____	____	____	____	____

Part I (Continued)

Information Characteristics	Strength of Approval or Disapproval 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
TROUBLESHOOTING TI						
1. Adequacy of Fault Verification	____	____	____	____	____	________
2. Test Instructions						
a. Level of Detail	____	____	____	____	____	________
b. Sequence of Tests	____	____	____	____	____	________
c. Ease of Access	____	____	____	____	____	________
d. Validity of Test Actions	____	____	____	____	____	________
3. Usability of Graphics						
a. Legibility	____	____	____	____	____	________
b. Understandability	____	____	____	____	____	________
c. Size	____	____	____	____	____	________
d. Help in locating test points	____	____	____	____	____	________
e. Level of detail	____	____	____	____	____	________
f. Format	____	____	____	____	____	________

Part I (Continued)

Information Characteristics	Strength of Approval or Disapproval 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
SUPPORT TI						
1. Table of Contents	____	____	____	____	____	____________
2. IPB	____	____	____	____	____	____________
3. Preparatory Instructions	____	____	____	____	____	____________
a. Indicator Preparation	____	____	____	____	____	____________
b. Task Preparation	____	____	____	____	____	____________
4. Others (describe)						

Part II — Electronic System Features

Electronic System Features	1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
Features of NTIPS Keys and Keyboard						
1. Spacing of keys	____	____	____	____	____	__________
2. Arrangement of keys	____	____	____	____	____	__________
3. Ease of operating keys	____	____	____	____	____	__________
4. Indication(s) that keys have been activated	____	____	____	____	____	__________
5. Reliability of keys (i.e., how well did the keys respond to use)	____	____	____	____	____	__________
Features of Touch-Sensitive Screen Operation						
1. Arrangement of touch labels	____	____	____	____	____	__________
2. Location of touch labels	____	____	____	____	____	__________
3. Readability of touch labels	____	____	____	____	____	__________
4. Responsiveness of system to using touch labels	____	____	____	____	____	__________
General Screen Features						
1. Adequacy of screen size for display of information	____	____	____	____	____	__________
2. Brightness of display	____	____	____	____	____	__________
3. Readability of display screens	____	____	____	____	____	__________
4. Contrast between displayed information and background	____	____	____	____	____	__________
5. Glare resistance of display screen	____	____	____	____	____	__________

Part II (Continued)

Electronic System Features	Scale Values 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
Techniques for Controlling Information Delivery						
1. Ease of using menus to obtain maintenance information	____	____	____	____	____	________
2. Ease of returning to the appropriate section in a set of procedures after branching to obtain additional information	____	____	____	____	____	________
3. Adequacy of features to exit from an inappropriate section of the data base (e.g, following an incorrect key press or equipment malfunction).	____	____	____	____	____	________
4. Adequacy of "prompts" on the display for assisting/guiding the operator	____	____	____	____	____	________

General Comments (use space below)

Part II (Continued)

BEST AND WORST CHARACTERISTICS OF ELECTRONIC DELIVERY OF TECHNICAL INFORMATION

Please check the three Best and three Worst characteristics of the electronic information delivery system you used in this test.

	Characteristic	Best	Worst
1.	Step by step text		
2.	Organization of procedures		
3.	Relation of text to graphics		
4.	Size of text characters		
5.	Font (letter style)		
6.	Spacing and layout		
7.	Size of graphics		
8.	Number of graphics		
9.	Nearness of graphic to related text		
10.	Detail of graphic		
11.	Graphic callouts		
12.	Touch screen		
13.	Size of touch boxes		
14.	Dependability of touch		
15.	Size of the electronic display		
16.	Electronic display legibility		
17.	Electronic display brightness		
18.	Electronic display glare		
19.	Printer		
20.	Menus		
21.	System response time		
22.	Ability to move around in the data base		

Thanks a lot. If we missed any characteristics that you believe to be important, pro or con, jot them down below.

Part III — Biographical Information

Name: ____________________________________ Date: ____/____/____
(last) (first) (middle)

Rating: ______________________________ Paygrade: ______________

Civilian Education, Highest Grade: ________

Service Schools Completed

(1) ____

(2) ____

(3) ____

Years in Navy: ____________ Years ____________ Months

Maintenance Experience:

Radar ________ Years ________ Months

What portion "0" level?: ______ Years ______ Months

What portion "I" level?: ______ Years ______ Months

Any other radar experience? ________ Yes ________ No

If yes, please specify: ______________________________________

____

____

Other Electronic Equipment ________ Years ________ Months

Other Electronic Equipment ________ Years ________ Months

Computer Experience:

(1) Have you ever taken a course in the use of a computer? _____ Yes _____ No

(2) Do you own a personal computer? _____ Yes _____ No

(3) Have you ever routinely used a computer as part of any job you have ever held?

_____ Yes _____ No

*This information will be held in confidence and will only be used for the purpose of this study of TI.

PART III — GENERAL COMMENTS AND PREFERENCES: ELECTRONIC DELIVERY VS. PAPER DELIVERY

1. If you had a choice of using an electronic or paper-based manual to perform tasks which would you choose?______________________________

2. In working with the technical documentation, was it easier with the electronic device? ___________ Or paper?____________

3. Which mode of presentation was better organized for your purposes? Electronic? _________ Or paper?_________

4. What do you see as the major advantages of the electronic presentation?

   ____

   ____

   ____

   The paper presentation? ____

   ____

   ____

INTERVIEW

You have just done troubleshooting using a conventional TI and the NTIPS electronic delivery system for corrective maintenance.

1. Based on this experience, which do you prefer? Conventional TI or NTIPS electronic delivery? Why?

2. How was your performance affected using NTIPS electronic delivery?

   a. Were any tasks made easier?

   b. Was your performance more accurate?

   c. Did you work more rapidly?

3. What problems, if any, did you have in using NTIPS electronic delivery?

4. What problems did you have in using conventional TI?

5. Do you think that both troubleshooting and corrective maintenance would be equally helped, or hindered, by using NTIPS electronic delivery? Why?

APPENDIX C

EXAMPLE OF TI TYPES USED IN TEST

Appendix C includes samples of each of the five types of Technical Information used during the tests. Two of these five approaches involved electronic delivery. For illustration purposes only, prints from the display screen were made and are incorporated herewith. These prints are intended only to show the presentation format, not the actual appearance of the data display.

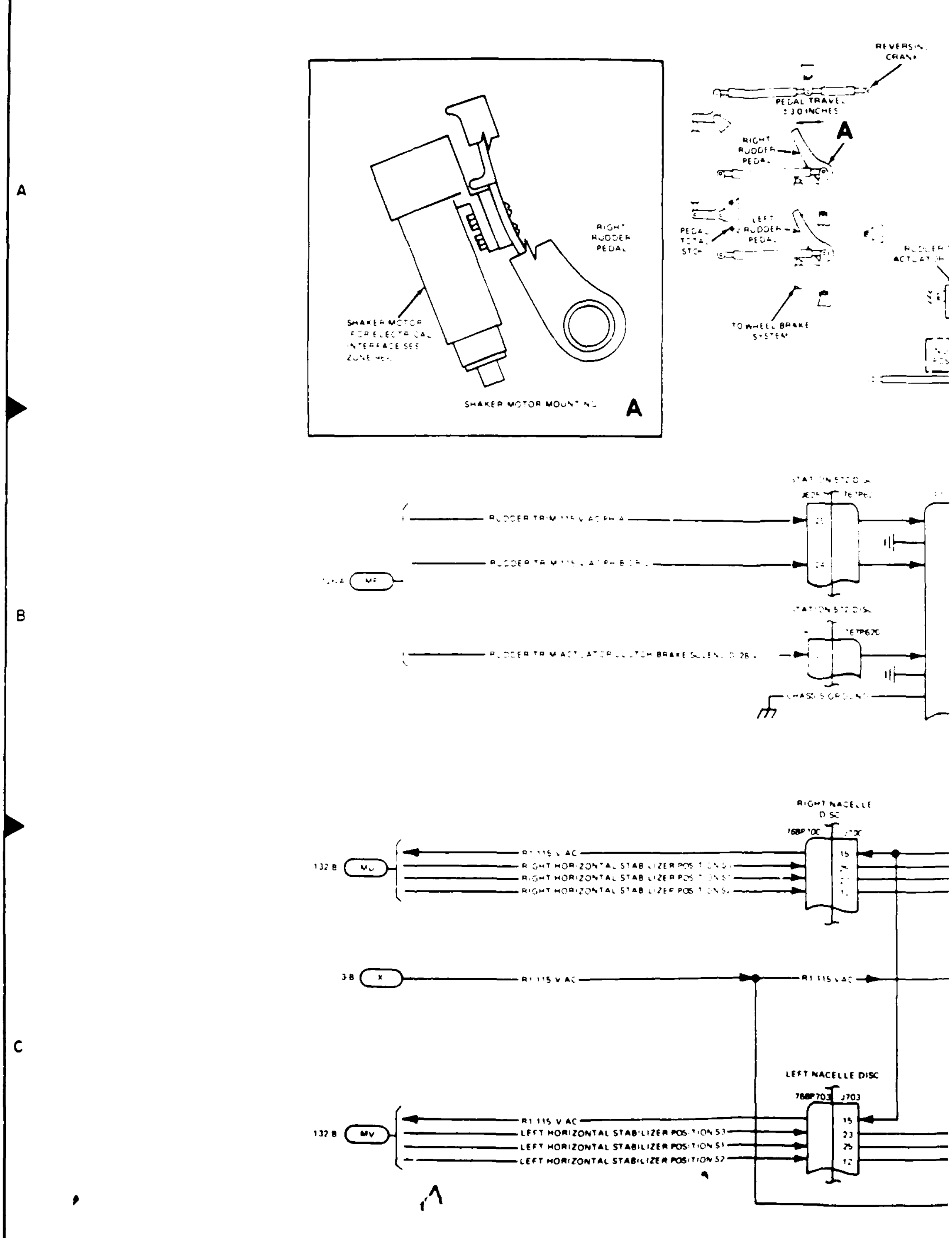
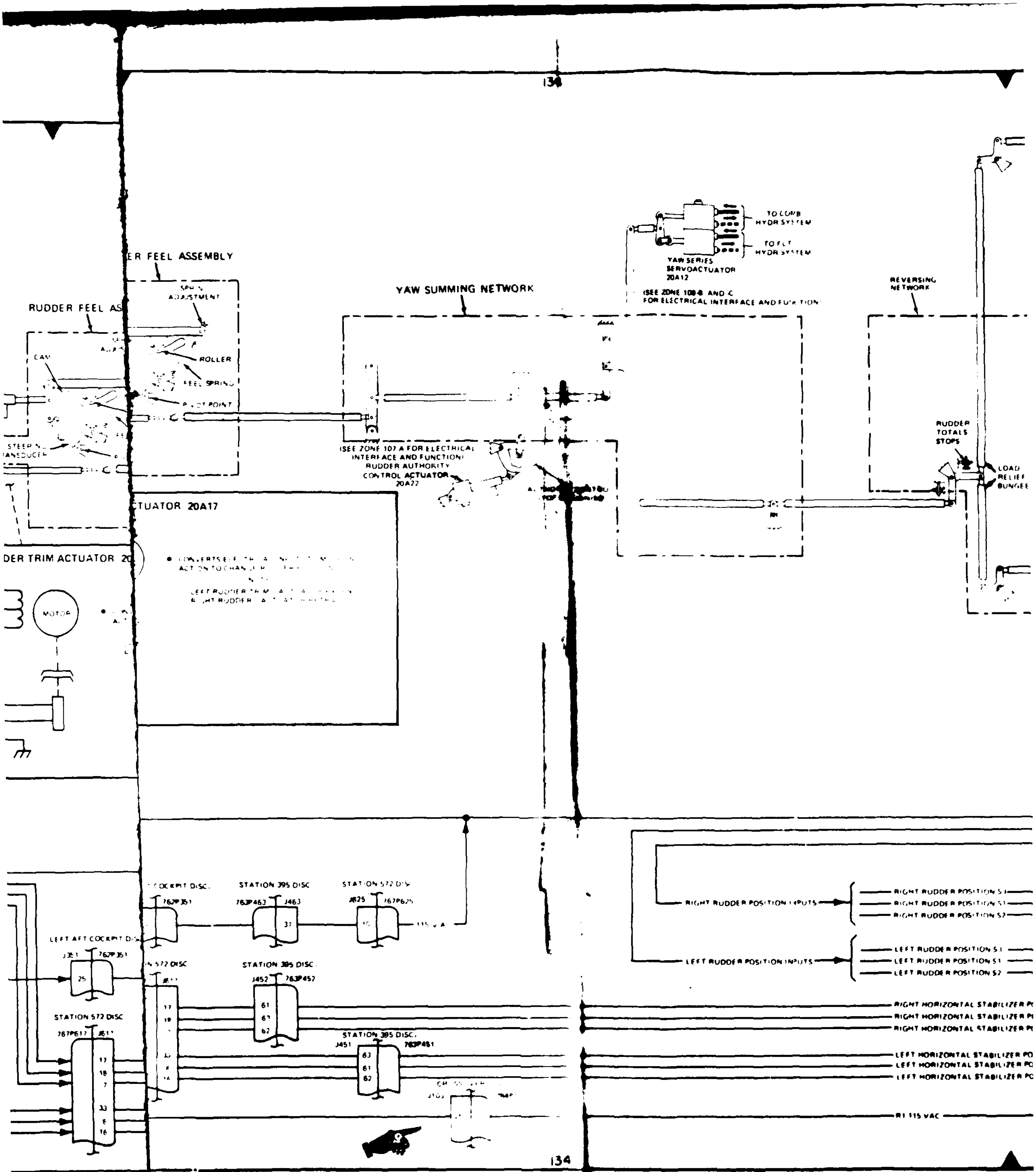
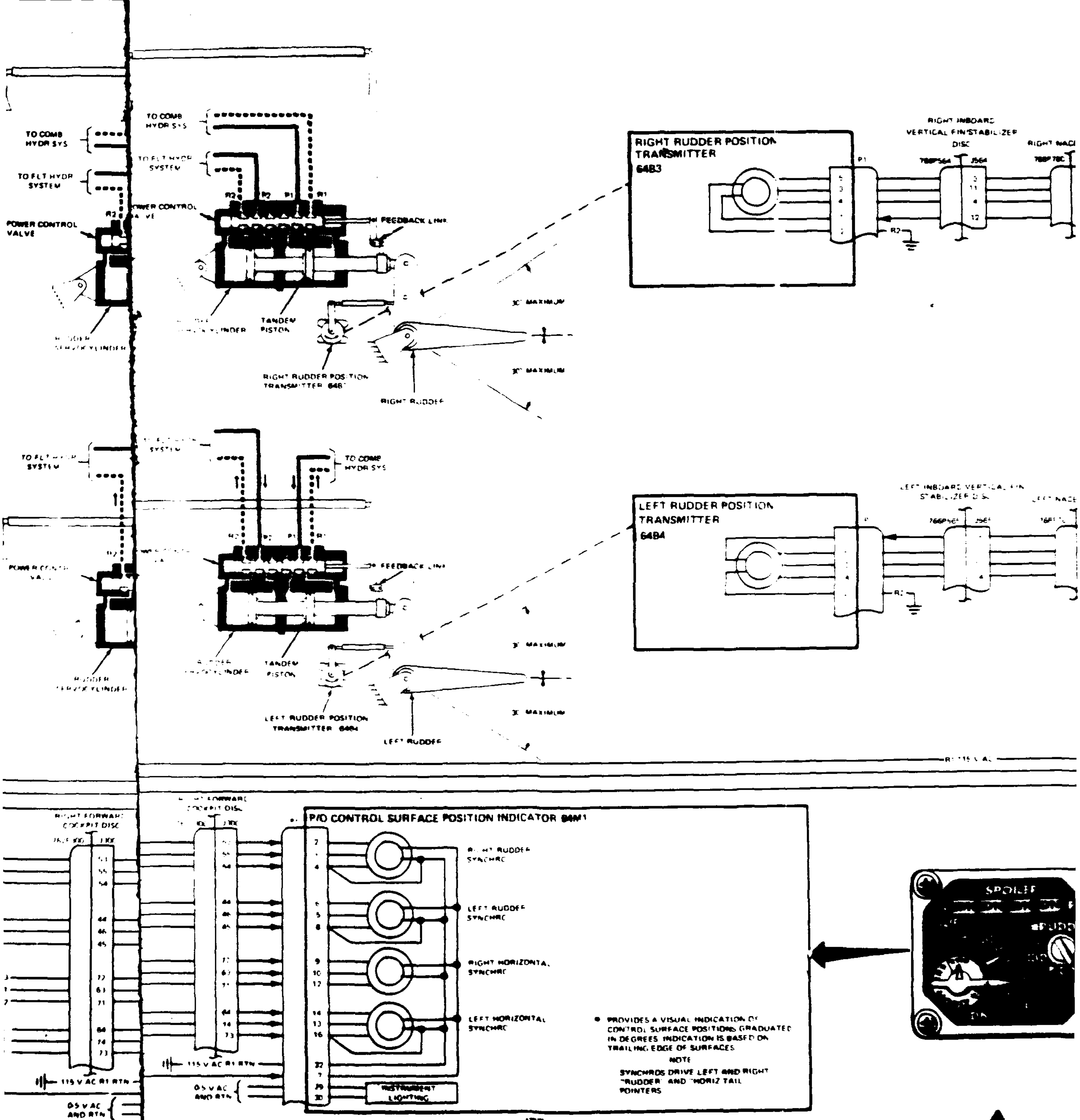


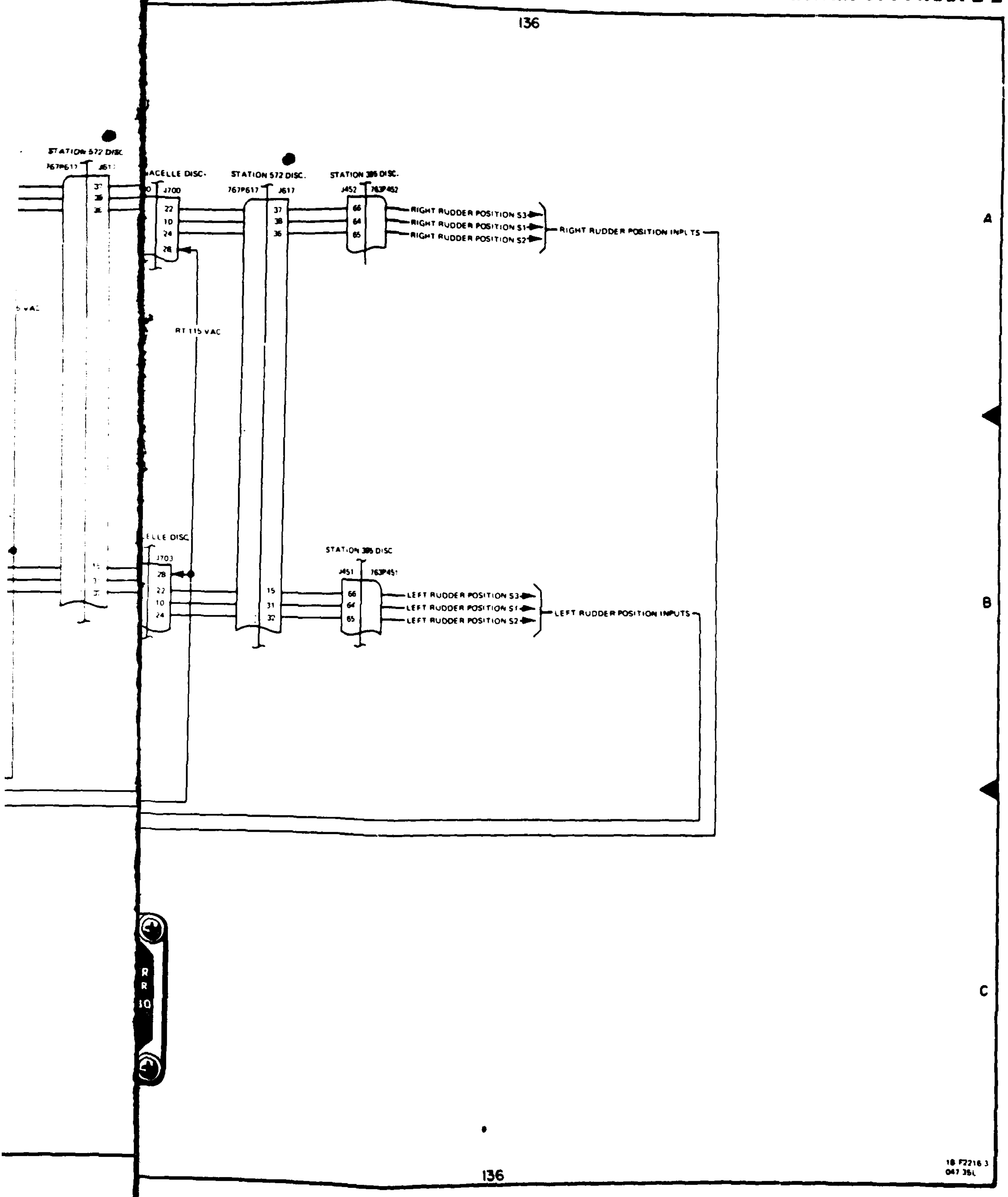
Figure 47. Rudder, Stabilizer, and Spoiler Control System Closed-L



l Diagram (Aircraft Serial No. 15982‌5 Thro 858 and Aircraft Modified by AFC 400) (Sheet 35)

Functional Diag


TO COMB HYDR SYS
TO FLT HYDR SYSTEM
POWER CONTROL VALVE
FEEDBACK LINK
TANDEM PISTON
RIGHT RUDDER POSITION TRANSMITTER 64B3
RIGHT RUDDER
30° MAXIMUM
RIGHT RUDDER POSITION TRANSMITTER
64B3
RIGHT INBOARD VERTICAL FIN/STABILIZER DISC
TO COMB HYDR SYS
LEFT RUDDER POSITION TRANSMITTER 64B4
LEFT RUDDER
LEFT RUDDER POSITION TRANSMITTER
64B4
P/O CONTROL SURFACE POSITION INDICATOR 64M1
RIGHT RUDDER SYNCHRO
LEFT RUDDER SYNCHRO
RIGHT HORIZONTAL SYNCHRO
LEFT HORIZONTAL SYNCHRO
INSTRUMENT LIGHTING
115 V AC R1 RTN
• PROVIDES A VISUAL INDICATION OF CONTROL SURFACE POSITIONS GRADUATED IN DEGREES. INDICATION IS BASED ON TRAILING EDGE OF SURFACES
NOTE
SYNCHROS DRIVE LEFT AND RIGHT "RUDDER" AND "HORIZ TAIL" POINTERS
SPOILER

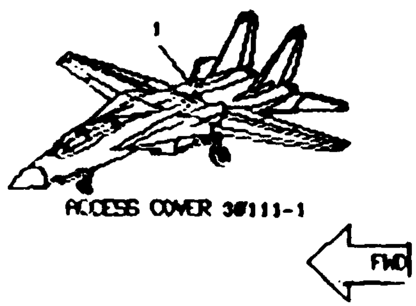

136
STATION 572 DISC
767P617
J617
NACELLE DISC.
J700
STATION 572 DISC.
767P617
J617
STATION 305 DISC.
J452
763P452
RIGHT RUDDER POSITION S3
RIGHT RUDDER POSITION S1
RIGHT RUDDER POSITION S2
RIGHT RUDDER POSITION INPUTS
RT 115 VAC
NACELLE DISC.
J703
STATION 305 DISC
J451
763P451
LEFT RUDDER POSITION S3
LEFT RUDDER POSITION S1
LEFT RUDDER POSITION S2
LEFT RUDDER POSITION INPUTS
A
B
C
136
1B F2216 3
047 35L

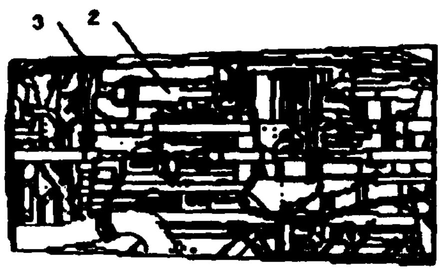
I. SAMPLE CONVENTIONAL TROUBLESHOOTING PAPER TECHNICAL MANUAL

1. If external hydraulic power is on, turn it off.

2. If external electrical power is on, turn it off.

3. Remove access cover 30111-1 (1) to gain access to the rudder trim actuator (3) at the forward end of the directional feel assembly (2).



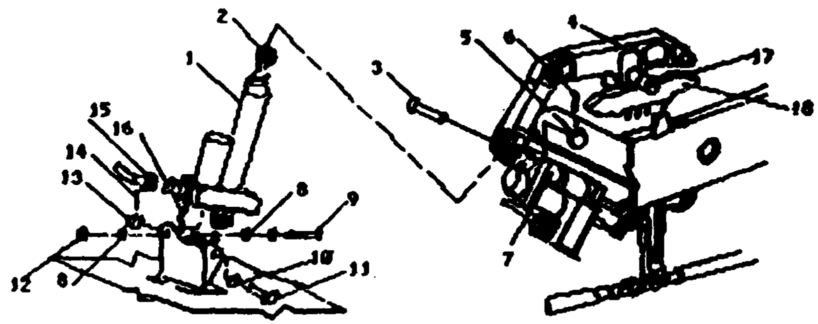


NEXT PAGE					COPY PAGE	HELP	STOP/EXIT

II. 3-PAGE SAMPLE OF A TEST PROCEDURE IN THE FIND TROUBLESHOOTING TI (REPRODUCED BY SCREEN

4. Disconnect connector 2AA17P1 (15) from rudder trim actuator.

5. Turn on external electrical power.



NEXT PAGE	BACK PAGE				COPY PAGE	HELP	STOP/EXIT

6. At pilot station, on INLET RAMPS/ENG CRANK/THROTTLE control panel, set and hold RUDDER TRIM switch (1) to L.

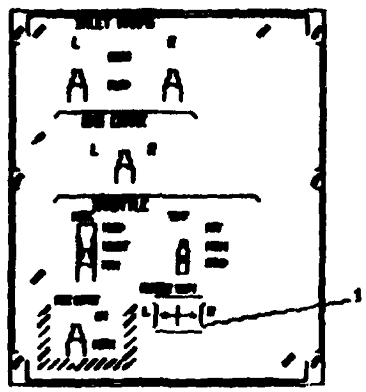
7. Locate pin 3.

8. Using AN/USM-311 or 8125A-01/AHG Multimeter, check for 115 Vac from 20A17P1 pin 3 to ground.

INDICATION: 115 Vac from pin 3 to ground is good.

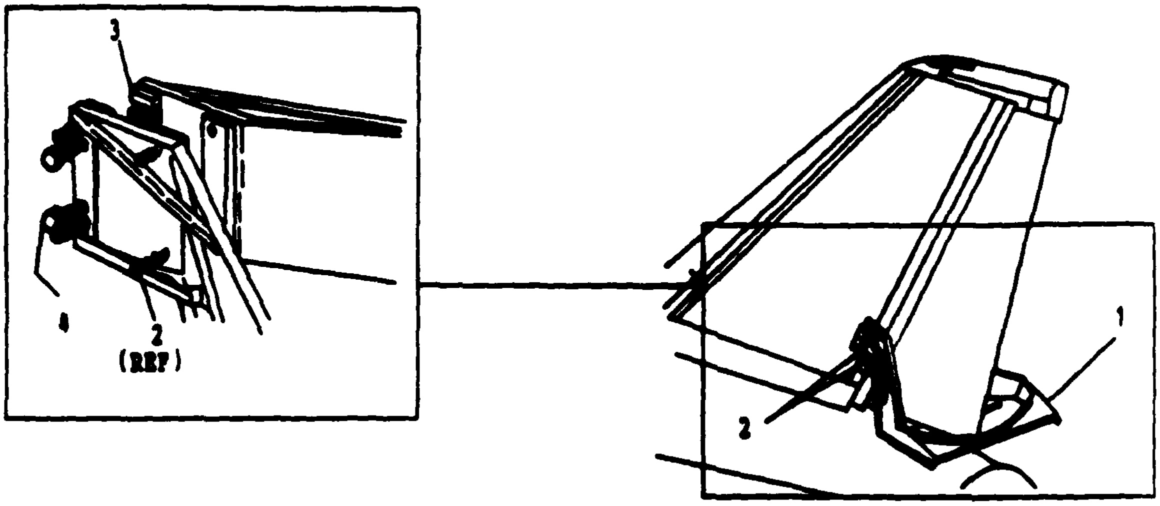
Use STOP/EXIT to return to FIND for entry of test results.

END OF TASK



INLET RAMPS/ENG CRANK/THROTTLE CONTROL PANEL

BACK PAGE | COPY PAGE | HELP | STOP/EXIT



RUDDER PROTRACTOR INSTALLATION

3. Attach the zeroed rudder protractor (1) to the vertical tail fin by tightening the four attaching screws (2).

4. Check whether the forward phenolic spacers (3) are fully against the vertical tail fin. If not, adjust the knurled screws (4) on the protractor until the gap between the spacers and the tail fin is equal on both sides.

END OF TASK

4-2.6. TASK 6. CHECK AND ADJUST RUDDER POSITIONING

4-2.6. ST1. CHECK RUDDER ZERO POSITION

1. Check that initial equipment condition has been established in accordance with the following procedures:

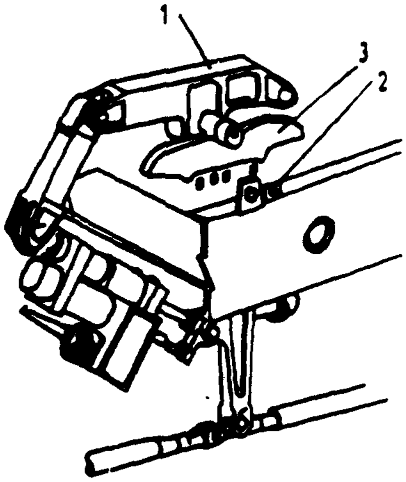
   5-2.1. TASK 1. Remove Hydraulic and Electrical Power
   4-2.5. TASK 5. Install Rudder Protractor

WARNING

To prevent possible death or injury to personnel and damage to equipment, all personnel and equipment must be clear of movable surfaces when the surfaces are being moved.

2. Make sure that all personnel and equipment are clear of movable surfaces per NAVAIR 01-F14AAA-2-1, WP010 00, Movable Surface Hazards.

3. Establish aircraft power in accordance with Task 2 (Chapter 1, para 1-2.2.).



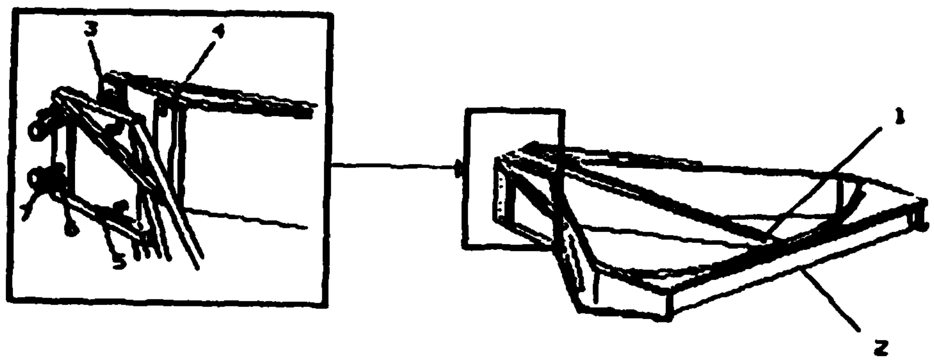
4. At the pilot station, on the left side console of the INLET RAMPS/ENG CRANK/THROTTLE control panel, operate the RUDDER TRIM switch until Rig Pin A51BC4900-5 can be inserted into the rig hole in the directional feel assembly (1), immediately below cam (3), through the rig pin holes (2) located on both sides of the directional feel assembly.

III. SAMPLE OF NTIPS PAPER TI

Copy available to DTIC does not permit fully legible reproduction

6. Loosen the four attaching screws that secure the indexer to the rudder protractor, and remove the indexer from the protractor.

Press y(YES) to continue with Subtask 2., Attach Rudder Protractor.



BACK PAGE	y YES	n NO		COPY PAGE	HELP	STOP/EXIT

IV. SAMPLE OF NTIPS ELECTRONICALLY-PRESENTED TI
(REPRODUCED BY SCREEN PRINTER FROM SCREEN DISPLAY)

Preliminary

ORGANIZATIONAL MAINTENANCE

RUDDER PROTRACTOR INSTALLATION AND REMOVAL

EFFECTIVITY: Aircraft Serial No. 157983 Through 157990, 158612 and Subsequent

Reference Material

General Aircraft Information	NAVAIR 01-F14AAA-2-1
Exterior Safety Check	020 00
External Hydraulic Power	038 03

Alphabetical Index

Record of Applicable Technical Directives

None

Support Equipment Required

Type or Part No.	Nomenclature
A51S62060	Rudder Protractor (2

Materials Required

None

V. CONVENTIONAL WORK-PACKAGE PAPER TI FOR A CORRECTIVE-MAINTENANCE TASK (4 PAGES)

1. INSTALLATION. (See figure 1.)

Note

Rudder protractor shall be zeroed (steps a through d) before installation on aircraft. If two protractors are required, both shall be zeroed.

a. If indexer is not secured to protractor, secure it with four screws provided on protractor.

b. Loosen locknuts that secure adjustment screws.

c. Rotate adjustment screws clockwise or counterclockwise until forward phenolic spacers are flush with indexer.

d. Check that indexer is at 0. If not, readjust screws until indexer is exactly at 0. Secure adjustment screws with locknuts.

e. Perform exterior safety check (NAVAIR 01-F14AAA-2-1, WP020 00).

f. Ensure that external hydraulic power is disconnected from aircraft and that NO POWER placard is placed over ground test pressure (GND TEST PRESS) fitting (NAVAIR 01-F14AAA-2-1, SWP038 03).

g. Remove four screws (two on each side) from rear spar of aircraft fin.

h. Loosen four screws, then remove indexer from protractor.

i. Secure protractor to fin with four screws on protractor.

j. Check whether forward phenolic spacers are fully against fin. If not, adjust knurled screws on protractor until gap between spacers and fin on both sides is equal.

k. Remove placard from GND TEST PRESS fitting.

2. REMOVAL. (See figure 1.)

a. Remove four screws that secure protractor to fin. Remove protractor.

b. Install four screws in rear spar of fin.

c. Secure indexer to protractor with four screws.

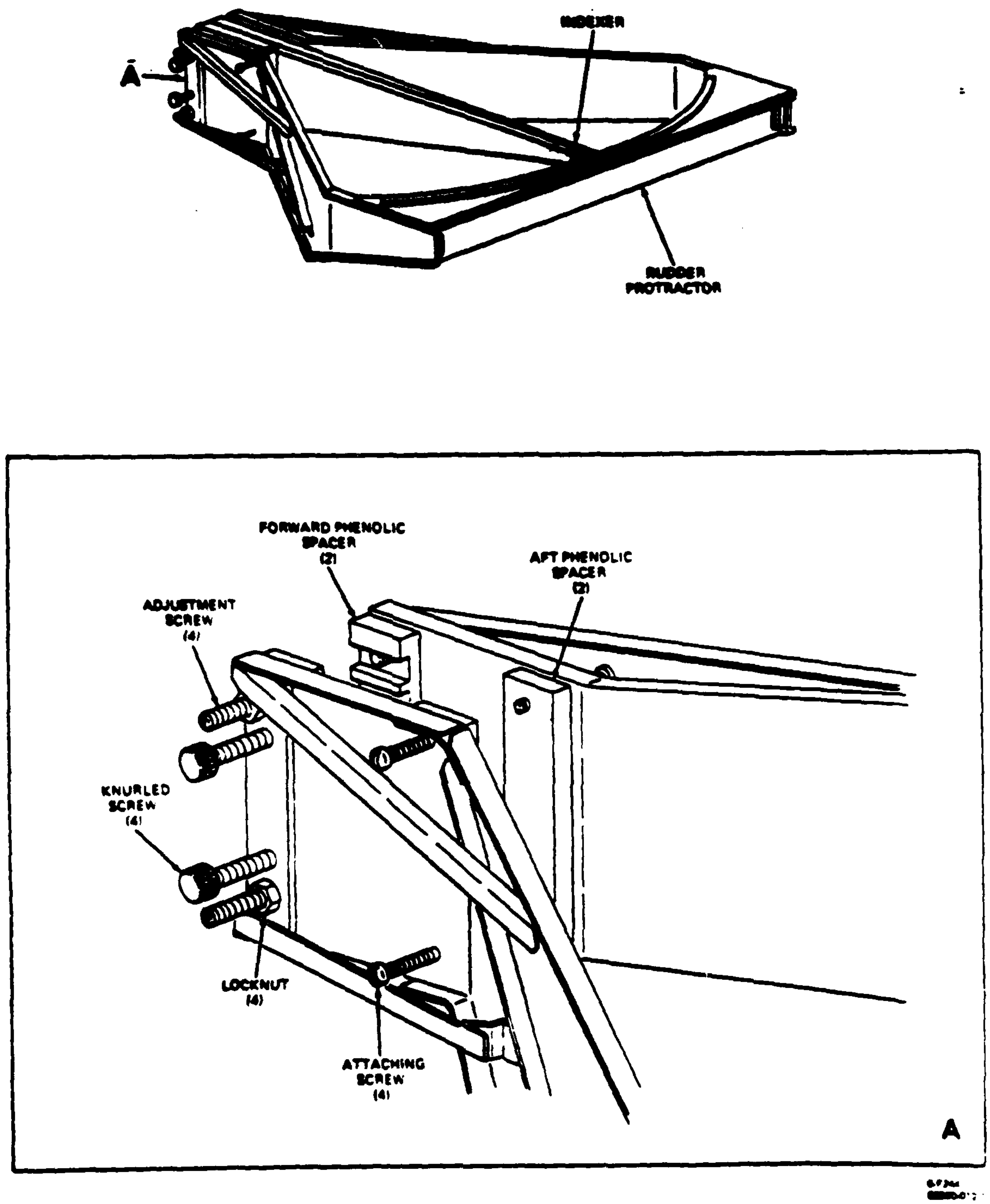
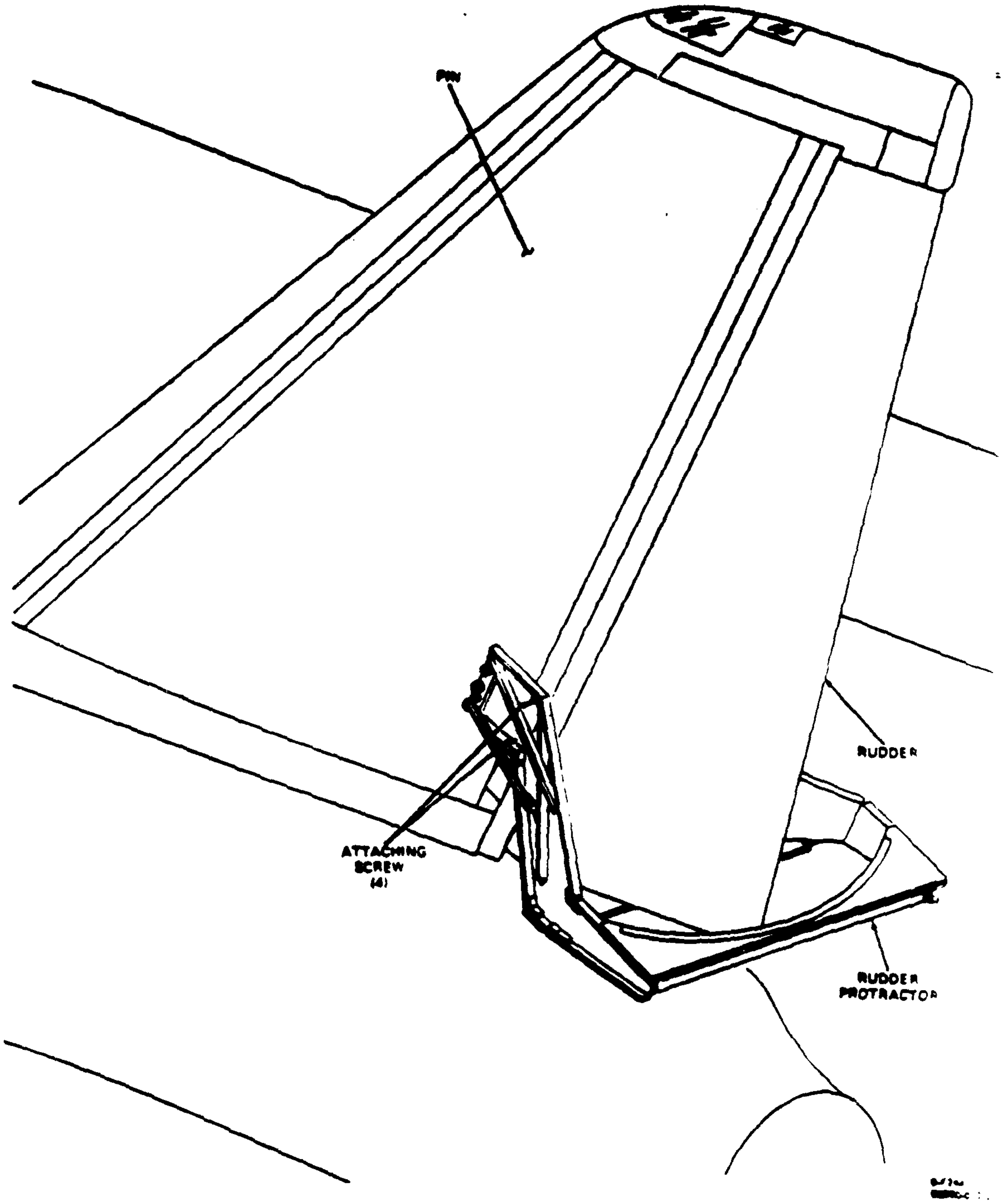


Figure 1. Removal and Installation of Rudder Protractor (Part 1 of 2)



Removal and Installation of Rudder Protractor (Part 2)

Figure 1 (Continued)

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